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This guide describes a dynamic model which simulates personnel flows in a Navy detailing community. Using historical accessions, continuation rates and promotion probabilities, the model projects an initial inventory to future periods. In each projection period the historical data can be updated to reflect possible changes. Sea/shore rotation patterns can be altered to produce a desired personnel distribution between sea, shore and neutral duty. All computer programs are listed, and some flow charts are provided.

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[20] A steady-state rotation model is described in CNA Research Contribution 380.

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THE EXPANDED SEA/SHORE ROTATION MODEL

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10 September 1979

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INTRODUCTION

The expanded rotation model provides a detailed simulation of actual personnel movements. It incorporates the following capabilities:

- describes a rating community whose inventory is variable over time
- treats each paygrade separately
- uses continuation rates for each length of service category
- simultaneously considers a different rotation pattern for each paygrade
- computes promotions into each paygrade.

It is useful for the analysis of questions of concern to enlisted rating coordinators (ERC) and detailers. For example, what effects would a change in E-3 rotation have on sea and shore distributions of personnel in the higher paygrades? The effect on rotation, due to promotions out of E-3, could be significant. A second kind of question is more general: what changes in current policies need to be made in order to attain a desired inventory size, paygrade distribution, and duty type distribution within each paygrade? To illustrate, a projection of the SeaBee community, using current continuation rates and accessions, predicts a total loss of 1,134 personnel within 5 years, and 947 of these will be from sea duty. If this were an acceptable reduction in size, but the loss of personnel from sea was considered to be too high, the expanded model could be used to determine alterations in rotation and accessions that would help maintain a more stable sea contingent in each paygrade. We shall present a general description of the model which will be further expanded and developed in subsequent chapters. The reader can also find a more detailed theoretical account in appendix A.

The expanded model can be applied to any detailing community in the Navy. Personnel movements are modeled as a network with flows. Each node, or cell, in the network consists of all individuals in the same paygrade group, duty type, length of service (LOS) category and with the same projected rotation date (PRD) to a <u>new</u> duty type. There are three duty types: sea, shore, and neutral. Paygrade groups are defined by the user. For example, when defining billet requirements it is standard practice to aggregate paygrades E-1, E-2 and E-3 in a single paygrade group; other paygrades can be similarly aggregated if desired. The user also defines the LOS categories. They may represent years in service, or the user may wish to define each LOS category as a 4-year period instead. In this case, the first LOS category would consist of all first-termers, while careerists would fall into higher categories. The time period used to measure LOS is the smallest period over which the personnel inventory can be projected. In the model, tour lengths are automatically measured in quarters of this time unit.

The paths which connect cells are either fixed or variable. Fixed paths represent (1) personnel flows, within the same paygrade group and duty type, from cells with given LOS and PRD to cells corresponding to LOS+1 and PRD-4 (if PRD > 4), and (2) flows into the next higher paygrade determined by promotions. It is assumed that an individuals' PRD is not altered by promotion. The rate of flow along each of these fixed paths is determined from historically observed attrition and promotion rates for each paygrade group, duty type and LOS category; we assume that these attrition and promotion rates are applied uniformly to each PRD cell.

The variable paths are defined by the rotation pattern. For example, rotation from sea to shore is modeled by establishing flows from each sea duty cell with PRD = 1 to shore cells in the next higher LOS category. The rates of flow along these paths are determined by the percentage of the rotating force at sea who are sent to each possible tour length or PRD cell.

At the start of a time period T the distribution of personnel is determined by the number of individuals in each cell. Once the connectivities and flow rates have been established, the PROJECT program computes the per-period flows in the network and then adds accessions to project the personnel distribution at the beginning of the (T+1)-th period.

Alterations in input data can be made at the beginning of each time period. All historical input data can be obtained from the Enlisted Master Record (EMR), and data for future time periods can be estimated by altering this historical input to conform to anticipated changes.

Besides the projection program, the user is provided with programs to make alterations in stored input data, and system parameters which allow the user to modify normal operations of the model. These features are provided for added flexibility in analyzing a projected inventory profile.

The model is programmed in APL to enhance its potential for real-time interactive use at a terminal. The ideal interaction would be a series of iterative steps in which a projection is alternated with selective modification of input. This should converge to a sea/shore policy that projects a satisfactory inventory.

The purpose of this manual is to provide a potential user with the specific information necessary to operate the ROTATIONMOD system. Although sample applications are discussed in chapter VI, they are not intended as a general analysis of the sea/shore rotation process. For this the reader may consult reference 1. The individual who is only interested in using the system does not need to know very much of the technical information that is presented here. For his purposes he can begin with chapter VI, and refer to other chapters and the appendices when necessary. The remaining chapters and the appendices provide information for the programmer who wishes to understand the system in sufficient detail to enable him to make alterations or develop supporting systems.

The model described in this paper does not include support systems such as programs for loading input data by computer. It is assumed that these have been developed by the user.

CHAPTER I

GENERAL SYSTEM DESCRIPTION

The computerized version of the expanded sea/shore rotation model (ROTATIONMOD) is written in APL/700 and is compatible with the Burroughs 6700 system. Once ROTATIONMOD has become operational, and desired modifications have been made, the model may be converted to FORTRAN. Because of the large quantities of input/output data involved, and the size of the data arrays which the model manipulates, difficulty was encountered in avoiding workspace and file space limitations. Consequently the devices used to overcome these limitations may require modification if the model is to be used on other APL systems or if it is converted to FORTRAN.

The advantages of APL are its interactive capability, the relative ease with which modifications to the system can be made, and the fact that APL is particularly suited to the manipulation of data arrays; hence the programs are considerably more simple than they would be if written in FORTRAN.

ROTATIONMOD is intended to be a real-time interactive model in which the operator can analyze consequences of decisions concerning rotation, continuation, promotions, and inventory structure. On the basis of this information, alterations in manpower policies can be made and tested until a suitable inventory profile is defined - or until it becomes clear that the desired objectives are incompatible. It cannot be rigorously demonstrated that this iterative process will always "converge" to an optimal solution; however, it is evident that restrictive hypotheses, which might guarantee such convergence, would severely limit the applicability of the model. As an alternative to such artificial restrictions, we have tried to make ROTATIONMOD as flexible a tool as possible.

Since it is impossible to foresee all potential applications of the model, users may find some features inappropriate or unnecessary, while other desirable capabilities are lacking. We have tried to make ROTATIONMOD easy to modify. Functions which would most likely be subject to modifications have a modular structure so that capabilities can be added or deleted without major structural changes in the model itself.

In the next few paragraphs we shall present an overview of the ROTATIONMOD system. Subsequent chapters will be devoted to more detailed descriptions.

The model may be applied to analyze any detailing community within the Navy, such as a rating or aggregate of ratings, which has the following structural characteristics:

- the personnel inventory can be divided into a number L of length of service (LOS) categories such that each individual in the L-th LOS at time period T will appear in the (L+1)-th LOS at period T+1 if he remains in the Navy.

- the personnel inventory can be divided into K pay-grade groupings such that an individual in paygrade group K ($K < \underline{K}$) has a probability of being promoted to paygrade group K+1

- the personnel inventory can be further subdivided into three duty types:
  (1) sea
  (2) shore
  (3) neutral

  (the numbers serve to identify duty types in ROTATIONMOD functions)

- at each time period, each individual has a projected rotation date (PRD) for rotation to a new duty type.

Thus each paygrade group inventory can be divided into "cells" consisting of all individuals with the same LOS, duty type and PRD. In addition to the parameters L and K, we shall use T to denote the maximal number of projection periods, and M to denote the largest tour length to which any individual will be assigned. The parameters K, L, M, and T are defined by the user, subject to realistic limitations. Generally K = 7 since the paygrades E-1, 2, 3 are usually aggregated. The projection periods are usually measured in years (because reliable continuation data is available for periods of 1 year). Because of file size limits, T = 5 is about as large as T can be. The LOS categories are 1-year periods so that L = 31. Finally, the PRD, or time remaining in duty type, is measured in quarters. Since it is DoD policy that no one should normally be assigned a tour length of more than 5 years, we usually take M = 20.

For a normal rating community, each paygrade inventory can be modeled as a 3-dimensional array. The entry in the (a, b, c)-th cell is just the number of individuals in duty type a and LOS category b, with a PRD of c quarters.

The model requires five APL files called MOD, FILE1, FILE2, FILE3, and FILE4, and a workspace called ROTATIONMOD. In the Burroughs 6700 system, each file has a 180,000 Byte capacity, and the workspace has a 85,000 Byte capacity. The file MOD is used to store most of the functions. These are brought into the workspace by a "calling function" having the general form shown in figure 1.

```
      ∇ FUNCTION
[1]     ⎕FX⌹[I]'MOD'
[2]     FUNCTIONN
[3]     ⎕EX'FUNCTIONN'
      ∇
```

FIG. 1: EXAMPLE OF A CALLING FUNCTION

The program FUNCTIONN is stored as a vector in component I of MOD. Statement [1] converts the vector representation into an APL function, which is executed in statement [2]. Statement [3] then expunges FUNCTIONN from the workspace. In several cases the calling function is indexed, and calls one of several functions (each named FUNCTIONN) according to the value of the index. This device is necessary because of limitations on workspace size. If more functions are added to the model, they can also be stored in MOD. Table 1 consists of a list of those functions which are currently stored in MOD.

TABLE 1

STRUCTURE OF MOD FILE

MOD components	Stored function	Calling function
1-6	PRINN	PRIN
7	GROUPP	GROUP
8	FILLL	FILL
9-23	PRINTT	PRINT
24	ADJPROBB	ADJPROB
25-31	HEADERR	HEADER
32-35	CHECKK	CHECK
36	FILEALTT	FILEALT
37	STATUSS	STATUS
38	ALTERR	ALTER
39	PROJECTT	PROJECT
40-49	CHANGEE	CHANGE
50	COMPTRR	COMPTR
51	COMPTAA	COMPTA
52	TRANSFERR	TRANSFER

FILE1 through FILE4 are data files which contain both input and output. The main functions ADJPROB and PROJECT read their output directly into these data files. The files are then accessed by using the PRINT and READFILE functions. Although we shall discuss the structure of these files in more detail in the next chapter, one structural aspect is noted here. Each of the data files is divided into two compartments of identical structure. Depending on the value of the workspace parameter OP1 (OP1 = 0 or 1), functions of ROTATIONMOD access the 0- compartment or the 1- compartment. In this way a copy of the initial input/output data can be stored in the 1- compartment, say, while the model is being used to modify data in the 0- compartment. Thus the initial and final inventory profiles can be compared.

The ROTATIONMOD system contains functions for data manipulation, and also user-specified parameters, such as OP1, which control the operation of these functions.

In the following detailed description of the model, we will elaborate further the outline sketched above.

CHAPTER II

FILE STRUCTURE

The structure of MOD has already been given sufficient attention. In this section we shall consider the data files. The number of components in each of these files is determined by the workspace parameters K and T. The file capacity of 180,000 bytes limits T to about 5 or 6 periods. As we have noted, each data file is divided into two compartments of identical structure. In table 2 we have indicated the structure of the 0- compartment of each data file. Throughout the discussion, we will emphasize the 0-compartment; the 1- compartment comprises the second half of the file. FILE1 contains basic input data, which will be described in chapter III.

FILE2 contains accessions to the inventory for each paygrade and time period from period 0 to period T-1. The accession information corresponding to a paygrade and time period is stored in two consecutive file components; thus accessions for paygrade group a in period b are located in FILE2 components (2a -1) + 2bK and 2a + 2bK.

FILE3 contains adjusted probabilities of promotion, which are computed by the function ADJPROB. These are inputs to PROJECT. Adjusted probabilities for each paygrade at period b are stored in component b + 1; components 1 through T contain this information. Components T + 1 and T + 2 contain, respectively, the current values of the "check" parameters C0A and C0P (these are described in chapter IV on workspace parameters). The 1- compartment of FILE2 is identical in structure, consisting of the components T + 3 through 2T+2 for adjusted probabilities, and 2T+3, 2T+4 for the "check" parameters C1A, C1P.

FILE4 contains two types of input/output data related to PROJECT. In the 0- compartment, the first component contains, for each projected paygrade inventory, the following totals:

- Initial inventory
- Inventory after attrition
- Promotions into paygrade
- Accessions into paygrade
- Paygrade limits for next period
- Projected inventory for next period.

Components 2 through 2K+1 contain the initial inventory. This data for paygrade a at time period b is located in components 2a+2bK and 1+2a+2bK.

TABLE 2

DATA TYPES

	Data type	File	Components
(1)	BILLETS[a] (BILTS)	FILE1	1
(2)	PAYGRADE LIMITS[a] (PGLIM)	FILE1	2
(3)	PROMOTION PROBABILITIES (PROBPROM)	FILE1	3
(4)	ELIGIBLE PROBABILITIES (ELIG)	FILE1	4
(5)	CONTINUATION (CONTINUATION)	FILE1	5 through 7
(6)	EARLY ROTATION (EROT)	FILE1	8
(7)	NORMAL ROTATION (NROT)	FILE1	9 through $8+2\underline{T}$
(8)	LATE ROTATION (LROT)	FILE1	$9+2\underline{T}$ through $8+4\underline{T}$
(9)	ACCESSIONS[a] (ACCESSIONS)	FILE2	1 through $2\underline{K}(\underline{T}+1)$
(10)	ADJUSTED PROBABILITIES (ADJPROBPROM)	FILE3	1 through $\underline{T}$
(11)	INVENTORY[a] (INVENTORY)	FILE4	2 through $1+2\underline{K}(\underline{T}+1)$
(12)	SUMMARY[a] (SUMMARY)	FILE4	1
(13)	PROMOTIONS[a]		
(14)	SURVIVING INVENTORY[a]		
(15)	PREPARED INVENTORY[a]		

[a]Indicates an additive data type. This will be defined in chapter IV.

This completes the description of the file system. We now proceed to describe in detail the data types which have been introduced here.

CHAPTER III

DATA TYPES

ROTATIONMOD requires a large data base which is stored in the data files as described in the previous chapter. Each of the distinct data types is listed in table 2. Data types are identified by the corresponding number in the READFILE and WRITEFILE functions. Each type is classified by several (or all) of the following characteristics:

- duty type
- length of service
- paygrade
- time period.

Data of a given type is generally stored in the form of a matrix or 3-dimensional array. The smallest unit of each data type that is processed by ROTATIONMOD is characterized by paygrade and time period. The structure of these data units, indicated within parentheses in table 2, depend on the data type. The structure and data unit for each data type will now be described. To be explicit, we again consider data stored in the 0-compartment.

BILLETS

Billet requirements are determined by the user for each duty type, paygrade and time period. These billets must be manned at a certain percentage, e.g., 100 percent sea and 70 percent shore. This data is not required for projecting an inventory, but is used as a basis for comparing ROTATIONMOD output with desired Navy goals. In the model, BILLETS are stored in the first component of FILE1 as a $\underline{K} \times (\underline{T}+1) \times 3$ array. The (a, b, c)-th entry is the billet requirement for duty type c in paygrade a at time period b-1. The unit data-type is called BILTS, and as illustrated in figure 2 it is a 3-component vector of billet requirements for sea, shore and neutral duty, respectively.

```
      BILTS
2445   645   15
```

FIG. 2: BILLET DATA UNIT (BILTS) CORRESPONDING TO A PAYGRADE AND TIME PERIOD

PAYGRADE LIMITS

The second component of FILE1 contains PAYGRADE LIMITS. These are the maximum allowed size for each paygrade at each time period. PAYGRADE LIMITS are stored as a ($\underline{T}$ + 1) x $\underline{K}$ matrix, in which the maximum endstrength for paygrade a at time period b is the (b + 1, a)-th entry; this entry is also the data unit PGLIM.

PROMOTION, ELIGIBLE AND ADJUSTED PROBABILITIES

The computation of promotions is based on input data stored in components 3 and 4 of FILE1. PROMOTION PROBABILITIES, in component 3, represent the historical percentage of personnel who have been promoted. This should be the average of several year's data in order to more accurately reflect persistent characteristics of promotion behavior (e.g. one expects that for each paygrade certain LOS categories would consistently have a greater percentage of their personnel promoted than others; that is, the promotion probability distribution over LOS categories should reflect characteristics of the paygrade). These percentages or "probabilities" of promotion are stored in the form of a 3 x $\underline{L}$ x $\underline{K}$ array in which the (c, b, a)-th entry represents the percent of the personnel in paygrade a, at duty-type c, and in LOS b who have historically been promoted (or an average of such percentages). As shown in figure 3, the data unit PROBPROM is a 3 x L matrix whose (c, b)-th entry is the probability of promotion for personnel in LOS b and duty type c.

Promotions are limited to personnel who have satisfied eligibility requirements determined by length in service and test scores. In ROTATIONMOD, this is represented by ELIGIBLE PROBABILITIES, which are stored in component 4, and represent the percentage of personnel in a (duty type, LOS, paygrade) cell which have fulfilled eligibility requirements. This data has the same 3 x $\underline{L}$ x $\underline{K}$ array structure as promotion probabilities. The data unit ELIG is a 3 x $\underline{L}$ matrix whose interpretation is analogous to PROBPROM.

In response to variations in endstrength requirements, PROJECT computes "adjusted probabilities of promotion" which are obtained by scaling the historical probabilities, but are never greater than the eligible probabilities. These ADJUSTED PROBABILITIES for each time period are stored in components 1 through $\underline{T}$ of FILE3 in the shape of a 3 x $\underline{L}$ x $\underline{K}$ array whose interpretation is the same as that of promotion and eligible probabilities. The data unit ADJPROBPROM is also similar to ELIG and PROBPROM.

```
     PROBPROM
0            0.4373768439   0.4134059274   0.4303751523   0.540380781    0.4976404976   0.532318642    0.5349505734
     0.5392709057   0.6580246101   0.2878857669   0.4798096115   0.4210526316   0.7            1
     1              0.5263157895   0              0              0              0              0
     0              0              0              0              0              0              0
     0              0
0            0.3990104541   0.3803334532   0.6547397852   0.4580935977   0.457733481    0.7572214427   0.3431426375
     0.3766336484   0.4606172271   0.5            0.7676953785   1              1              0
     0              0              0              0              0              0              0
     0              0              0              0              0              0              0
     0              0
0            0.3970104541   1              0              0              0              0              1
     0              0              0              0              0              0              0
     0              0              0              0              0              0              0
     0              0              0              0              0              0              0
     0              0
```

FIG. 3: PROMOTION PROBABILITIES DATA UNIT (PROBPROM0 CORRESPONDING TO A PAYGRADE

CONTINUATION

The continuation data for time period T consists of the percentage of survivors from period T to period T + 1 for each paygrade and each LOS category. Since nearly all personnel retire at the end of 31 years of service, the model is based on the assumption that continuation rates for LOS 31 are zero for all paygrades and all time periods. The user must take care when loading the data base to insure that this condition is satisfied.

Generally, continuation rates will be LOS "bag" rates such as those obtained by PROPHET (reference 2), or directly from the EMR. Provision is made for using different rates for each of the three duty types should this information be available. Continuation data for sea, shore and neutral is loaded in FILE1 components 5, 6, and 7 respectively. Each of these components contains a $\underline{T} \times \underline{L} \times \underline{K}$ array in which the (c, b, a)-th entry is the percent of survivors through time period c in LOS b and paygrade a.

The data unit CONTINUATION corresponding to a paygrade and time period is a $3 \times \underline{L}$ matrix of LOS continuation rates for each duty type - again similar to PROBPROM.

ROTATION

The input data which specifies a rotation pattern falls into three categories: early rotation, normal rotation and late rotation. Personnel who rotate normally go to a particular duty-type for a specified number of quarters - their projected rotation date (PRD). At the end of this time, they rotate to a different duty type. Most individuals should be following this normal pattern; however, exceptions occur when tour lengths are extended or shortened due to factors such as operational holds, humanitarian considerations, leave taken between tours or participation in schools. There are six types of rotation in the normal pattern:

(1) sea to shore
(2) sea to neutral
(3) shore to sea
(4) shore to neutral
(5) neutral to sea
(6) neutral to shore.

The EARLY ROTATION data is stored in component 8 of FILE1 as a $\underline{T} \times 6 \times \underline{K}$ array, in which the (c, b, a)-th entry is the percentage of personnel in paygrade a at time period c with rotation type b. The data unit EROT for a particular paygrade and time period is a 6-component vector whose b-th component is the percent of rotating personnel whose rotation type is b.

EROT
0.1251862891 0 0.07373271889 0.004608294931 0 0.5

FIG. 4: EARLY ROTATION DATA UNIT (EROT) DETERMINED BY PAYGRADE AND TIME PERIOD

We have assumed that individuals who rotate early will be assigned to a normal tour in their new duty type. Normal assignments are determined at each time period by the NORMAL ROTATION data, which is in the form of a 6 x $\underline{M}$ x $\underline{K}$ array. The (b, c, a)-th entry is the percentage of paygrade $\bar{a}$ with rotation type b who rotate to a tour length c quarters.

These arrays are large (approximately 14,000 bytes) and if loaded directly into file components, would take up excessive space. Therefore it was necessary to separate each array into a (0,1)-array R, whose non-zero entries correspond to the non-zero entries of the original array, and a vector V whose components are the non-zero entries of the array. In APL this is done by the commands

```
R←0 ≠ ARRAY
V←(,R)/,ARRAY.
```

Since most entries in a rotation array are zero, this results in a substantial reduction in space requirements. The original array is given by the expression

```
(3, L, M) ⍴ (,R)\V.
```

The arrays R and V are stored in two consecutive components of FILE1 (see table 2). For time period T, R is located in component T + 9, and V is stored in component T + 10.

The data unit NROT is a 6 x $\underline{M}$ matrix (an example is shown in figure 5). The (a, b)-th entry is the percentage of rotation type a personnel who are sent to a tour length of b quarters.

LATE ROTATION data is treated similarly. For each period it is represented as a 3 x $\underline{M}$ x $\underline{K}$ array in which the (c, b, a)-th entry is the percentage of personnel in paygrade a and duty type c, with a PRD of 1 through 4, whose PRD is extended to b remaining quarters. The data unit LROT (figure 6) is a 3 x $\underline{M}$ matrix in which the (c, b)-th entry is the percentage of personnel in duty type c who are assigned a new PRD of b quarters. Again, due to space considerations, this data has been separated into a(0,1)-array and a vector which are stored in consecutive components of FILE1 as indicated in table 2.

```
     NROT
0                     0                     0                     0                     0                     0.00999
     0.03996               0.8991                0.03996               0.00999               0                     0
     0                     0                     0                     0                     0                     0
     0                     0
0                     0                     0                     0                     0                     0.00001
     0.00004000000001      0.0009000000002       0.00004000000001      0.00001               0                     0
     0                     0                     0                     0                     0                     0
     0                     0
0                     0                     0                     0                     0                     0
     0                     0                     0                     0                     0                     0
     0                     0.00999               0.03996               0.8991                0.03996               0.00999
     0                     0
0                     0                     0                     0                     0                     0.00001
     0.00004000000001      0.0009000000002       0.00004000000001      0.00001               0                     0
     0                     0                     0                     0                     0                     0
     0                     0
0                     0                     0                     0                     0                     0
     0                     0                     0                     0                     0                     0
     0                     0.005                 0.02                  0.45                  0.02                  0.005
     0                     0
0                     0                     0                     0                     0                     0.005
     0.02                  0.45                  0.02                  0.005                 0                     0
     0                     0                     0                     0                     0                     0
     0                     0
```

FIG. 5: NORMAL ROTATION DATA UNIT (NROT) DETERMINED BY PAYGRADE AND TIME PERIOD

	LROT															
0	0	0	0	0.155	0.017	0.009	0.009	0	0.009	0.009	0	0	0	0	0	0
	0	0	0													
0	0	0	0	0.166	0.031	0.009	0.018	0.004	0.009	0	0.004	0	0	0	0	0
	0	0	0													
0	0	0	0	0.667	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0													

FIG. 6: LATE ROTATION DATA UNIT (LROT) DETERMINED BY PAYGRADE AND TIME PERIOD

ACCESSIONS AND INVENTORY

In the model, accessions are interpreted to include lateral transfers in and out of a rating as well as new personnel entering at the lower paygrade levels. Thus lateral transfers out of a rating are represented by a negative number. Also, a significant number of people attend schools between duty tours, and for this period they are not counted as part of the distributable inventory. This can be modeled by considering school candidates as negative accessions to the inventory when they enter school and positive accessions when they are re-established in the normal paygrade inventory.

Paygrade accessions and inventory are both represented as 3 x $\underline{L}$ x $\underline{M}$ arrays in which the (a, b, c)-th entry is the number of accessions to/from (or personnel in) the cell defined by duty type a, LOS b and tour length c. There is one such array for each paygrade and time period. In the case of inventory, the initial period 0 inventory is input, and all subsequent periods represent output from the PROJECT program. These are the largest data elements in ROTATIONMOD and must be stored as pairs consisting of a (0, 1)-array and a vector as previously described. For both accessions and inventory, the data unit is the entire 3-dimensional array.

SUMMARY

The summary data, stored in component 1 of FILE4 is also output from PROJECT; and for each paygrade and time period T it consists of totals of the following data types:

Initial inventory at period T
Inventory after attrition
Promotions into paygrade
Accessions into paygrade
Paygrade limits for period T+1
Projected inventory for period T+1

It is stored as a $\underline{T}$ x 7 x $\underline{K}$ array. The data unit SUMMARY is a 7-component vector as shown below.

```
      SUMMARY
  1  3875.185336  3043.729128  0  2615  3825  3948.321063
```

The first component indicates the paygrade and the remaining six are totals for each of the above data types.

In table 2 we summarized all data types. The table also includes three which have not been described. These are not stored in the files, but can be computed from stored data. For example, the SURVIVING INVENTORY is simply the paygrade inventory after attrition. PROMOTIONS is the array of actual promotions in each inventory cell computed by applying the adjusted promotion probabilities to the surviving paygrade inventory. The PREPARED INVENTORY is the inventory array which results after attrition and promotions have been completed. That is, the inventory of a paygrade just before it is rotated. Each of these inventory-type data arrays represents a particular stage in projection to the next period. This data can be printed by the PRINT function described in chapter V; thus the user can examine in detail the steps in the transformation of an inventory into the next periods' inventory.

We now turn to a description of the workspace parameters which provide added flexibility by allowing the user to modify certain aspects of the projection process.

CHAPTER IV

WORKSPACE PARAMETERS

In addition to the file system, which has been described, and the programs which will be discussed in the next chapter, ROTATIONMOD utilizes parameters which define file size and control the operation of certain functions. The parameters $\underline{K}$, $\underline{L}$, $\underline{M}$, $\underline{T}$ and OP1 have already been defined; a summary description of all parameters can be found in appendix C.

The rotation pattern, as we have seen, consists of early, normal and late rotation components. In order to increase flexibility, we have introduced parameters OP2 and OP3 to control the effects of early and late rotation. If OP2 = 1 then the late rotation data will enter into the rotation computation. However if the user sets OP2←0, PROJECT will ignore late rotation data. Similarly, if OP3 = 1 early rotation information will be utilized while if OP3 = 0 it will be ignored. Thus, for example, the operator can study consequences of a purely normal rotation pattern, without destroying other rotation data, by setting OP2←OP3←0.

Normally, because of file size limitations, it is necessary to restrict $\underline{T} \leq 5$. That is, an initial inventory can be projected at most 5 periods. However, the effects of certain aspects of a sea/shore policy may not appear for several years (e.g. a change in rotation patterns may have no effect on duty type distributions for three or four years). The operator can analyze an inventory profile over a longer time span than would otherwise be possible by using OP4. This parameter is a 2- component vector. If OP4[1] = 0, it has no effect. However, if OP4[1] = 1 and OP4[2] = T, ADJPROB and PROJECT will re-define the projection period to be T, and will use time period T - 1 data to operate on inventory stored in time period T. The projected inventory is stored in the time period T space, destroying its previous contents. In this way the time period T inventory can be projected to any future period using, at each projection, the period T-1 input data. The use of OP4 will be more completely described in chapter IV.

The user may be interested in aggregating certain paygrades. For example, because of the one-up/one-down principle for filling paygrade billets, paygrades E-4 and E-5 could be combined in an analysis of personnel available to fill E-4 billets. For all additive data types, this can be accomplished by an appropriate setting of the vector OP5 (the additive data types are defined by an "a" in table 2). Roughly, a data type is additive if the data for an aggregate of paygrades is the sum of the data for the individual paygrades. Promotions are the only exeption to this rule; it is clear that promotions out of an aggregate are the same as promotions out of the highest paygrade in the aggregate.

The parameter OP5 must satisfy the following conditions:

- All components lie in the interval between 1 and $\underline{K}$ inclusive.
- OP5 has an even number of components n
- The number n of components must lie between 2 and 2$\underline{K}$ inclusive.

Under these conditions, OP5 defines n/2 paygrade groups in which the m-th paygrade group is the aggregate of all paygrades k in the interval OP5[2m-1] $\leq$ k $\leq$ OP5[2m]. For example, if OP5 = 1, 4, 6, $\underline{K}$ then two paygrade groups are defined. The first is the aggregate of paygrades 1, 2, 3, and 4 and the second is the aggregate of paygrades 6 through $\underline{K}$. The function GROUP aggregates additive data for the paygrade groups defined by OP5.

The ordinary paygrade structure is obtained by the APL command OP5 ← 1, 1, 2, 2, ..., $\underline{K}$, $\underline{K}$. In most cases OP5 should initially be set to this value and altered only for special considerations.

The parameter OP6 serves the analogous purpose of aggregating LOS categories for additive data types. This vector must satisfy the conditions for OP5 with $\underline{K}$ replaced by $\underline{L}$. Normally the value of OP6 would be specified by the APL command OP6 ← 1, 1, 2, 2, ..., $\underline{L}$, $\underline{L}$.

Finally, there are four "check" parameters: C0A, C0P, C1A and C1P. These are binary vectors stored, respectively, in components $\underline{T}$ + 1, $\underline{T}$ + 2, 3 + 2$\underline{T}$ and 4 + 2$\underline{T}$ of FILE3. The number of components in C0A is the number of time periods, starting with period 0, for which adjusted probabilities have been computed in the 0-compartment; and the number of components in C0P is the number of periods to which the inventory has been projected (initial inventory is by definition the projected inventory at time T = 0) in the 0-compartment. The vectors C1A and C1P have an analogous interpretation for the 1- compartment.

Immediately after the inventory has been projected T periods, C0P (or C1P if OP1 = 1) is a vector consisting of T + 1 zero components. If input data affecting PROJECT is changed at the T - 1 time period by using CHANGE to make selective alterations, a 1 is automaticallly placed in component T of C0P (or C1P). Figure 7 shows a sample setting. Similarly alterations in data on which

```
TM = 0  1  2  3  4  5

C0A = 1  1  0  0  0
C0P = 1  1  0  0  0  0

C1A = 0  1
C1P = 0  0
```

FIG. 7: A SETTING OF THE CHECK VECTORS

the ADJPROB program depends are reflected in C0A or C1A by a 1 in the appropriate component. These check parameters provide the operator with a convenient check on the consistency of the data in the file system. ADJPROB and PROJECT will give error messages if the operator tries to use these programs after altering data for a prior period. The current value of all workspace parameters can be obtained by using the STATUS function.

This completes our discussion of workspace parameters. The relations between them and the ROTATIONMOD functions are summarized in table 3.

TABLE 3

INTERRELATION OF FUNCTIONS AND WORKSPACE PARAMETERS

	OP1	OP2	OP3	OP4	OP5	OP6	C0A	C0P	C1A	C1P
ADJPROB	+	0	0	+	0	0	1	1	1	1
ALTER	+	0	0	0	0	0	0	0	0	0
ATTRITION	+	0	0	+	0	0	0	0	0	0
CHANGE	+	0	0	0	0	0	0	0	0	0
CHECK	+	0	0	0	0	0	-	-	-	-
COMPTA	+	0	0	0	0	0	0	0	0	0
COMPTR	+	+	+	0	+	0	0	0	0	0
FILEALT	+	0	0	0	0	0	-	-	-	-
FILL	+	0	0	0	0	0	0	0	0	0
FFF	+	0	0	0	0	0	0	0	0	0
GROUP	+	0	0	0	+	+	0	0	0	0
HEADER	0	0	0	0	0	0	0	0	0	0
PREPINV	+	+	+	0	0	0	0	0	0	0
PRIN	0	0	0	0	0	0	0	0	0	0
PRINT	+	0	0	0	+	+	0	0	0	0
PROJECT	+	+	+	+	0	0	-	-	-	-
STATUS	+	+	+	+	+	+	+	+	+	+
TRANSFER	0	0	0	0	0	0	0	0	0	0
READFILE	+	0	0	0	0	0	0	0	0	0
WRITEFILE	+	0	0	0	0	0	0	0	0	0

+ means that the parameter value affects the operation of the function, while - indicates that the function affects the parameter value.

CHAPTER V

ROTATIONMOD FUNCTIONS

The functions which comprise ROTATIONMOD are described in this chapter. The theoretical basis for the computations are discussed in appendix A.

The functions fall into two categories: those which the user must operate, and functions which appear as subroutines in these user-oriented functions. The user-oriented functions are listed below:

ADJPROB
CHANGE
COMPTA
COMPTR
FILL
PRINT
PROJECT
STATUS
TRANSFER
READFILE
WRITEFILE

In this chapter we shall give a general description of each function. Appendix B contains flow diagrams and a complete listing of all functions.

User-Oriented Functions

These are the programs that the operator must use when applying ROTATIONMOD. We have tried to minimize the knowledge of APL necessary for their operation by providing error message responses and conversational program entries where appropriate.

ADJPROB

Historical probabilities of promotion (see chapter III) are inputs to the expanded rotation model. However, promotion behavior is modified by time-dependent factors such as changes in end-strength requirements, accessions or continuation; therefore the actual promotions in any period will depend on changes in these factors. This requires an adjustment of the historical probabilities. The modeling of this response is carried out by the program ADJPROB and the subroutine FFF.

In order to compute adjusted promotion probabilities for time period T, the user types ADJPROB T. The results of the subsequent computation are stored in FILE3 (see chapter II). The conditions required for using this program are listed below:

- $0 \leq T \leq \underline{T}$
- Inventory has been projected to period T.
- Subsequent to this projection, no input data for previous periods has been altered.

A violation of any of these conditions results in an error message and termination of the program. The compartment from which input data is read is determined by the value of OP1.

Normally, when OP4[1] = 0, ADJPROB will read data from the period T spaces and store computed adjusted probabilities in the period T space. However, if OP4[1] = 1, then no matter what value of T is entered, ADJPROB will redefine it to be OP4[2]-1. When OP4[1] = 1, ADJPROB and PROJECT can be used to project an inventory to any future period, using at each such projection the input data corresponding to time period OP4[2]-1. This will be described in more detail in the discussion of PROJECT and in chapter VI.

CHANGE

This function enables the user to make selective alterations in the data base. To use CHANGE, the operator types CHANGE 'DATA TYPE.' Then in response to the displayed prompt the user specifies the data compartment which is to be changed. The program then responds with further prompts asking for paygrades and time periods at which the change is to be made. The desired change is then entered in the form specified by the prompt.

CHANGE has the modular structure shown in figure 1; each of the component functions is called CHANGEE. At the present time, CHANGEE programs have been written for the data types "PAYGRADE LIMITS", "CONTINUATION", "EARLY ROTATION", "NORMAL ROTATION", "LATE ROTATION", and "ACCESSIONS." Once it has been established what type of alterations are most useful for a particular data type, the corresponding CHANGEE program can be written or modified and stored in the MOD file.

COMPTA

This function is used to give an approximation to the number of accessions needed each period to bring the inventory to a specified level at the end of a specified time period. If it is desired to have a total inventory I at the end of period T, the inventory must first be projected T periods using current input data. Then the user types COMPTA, and enters the values of I and T when prompted. The function then computes an estimate of the accessions required per period to attain the desired force level at period T. The inventory should be projected again to T periods using the new accession levels estimated by COMPTA; if this projection is still not sufficiently close to the desired level, COMPTA can be repeated; COMPTA is intended to be used iteratively in conjunction with the PROJECT function.

```
      COMPTA
ENTER NEW INVENTORY SIZE
⎕:

ENTER TIME PERIOD AT WHICH NEW INVENTORY IS TO BE ATTAINED
⎕:
```

FIG. 8: INPUT FORMAT FOR COMPTA

COMPTR

This function is intended to help the user decide what type of normal rotation patterns will provide a desired personnel distribution between duty types. The steps needed to activate COMPTR are shown in figure 9. The user types COMPTR and is prompted to enter a paygrade, duty type, time period T_1, and a time period T_2 subsequent to T_1. The output is a table as shown in figure 10. The values of parameters affecting this computation are indicated. In this example the user was interested in analyzing the effects of rotation changes on the total number of personnel in paygrade 2 at shore in period 2. In general, the output gives the number of personnel rotating to the duty type in period T_1 who will rotate from that duty type in period $T_2 - 1$, if all were originally sent to the indicated tour length.

In order to clarify the use of this function, we shall describe the basis of the computation. For a given paygrade and time period T_2, the number of personnel in a duty type is affected by how many rotate from that duty type in period $T_2 - 1$. This number in turn, is affected by the rotation policy at periods prior to $T_2 - 1$. For example, personnel rotating into the duty type in period T_1 will be up for rotation in period $T_2 - 1$ only if they are sent to tour lengths of $4(T_2-T_1-1)-3$ to $4(T_2-T_1-1)+3$ quarters. Therefore by changing the percentages of personnel who are sent to these tour lengths in period T_1, the user can affect the size of the duty-type in period T_2. For instance in figure 10 the entry in the last column of the first row

```
     COMPTR
FOR A PAYGRADE GROUP (DEFINED BY OP5) AND DUTY TYPE,
COMPTR DESCRIBES THE EFFECT OF CHANGES IN NORMAL ROTATION
AT A PERIOD T1 ON THE TOTAL PERSONNEL IN THE DUTY TYPE AT A
SUBSEQUENT PERIOD T2≥1+T1
ENTER PAYGRADE GROUP
⎕:

DUTY TYPE: SHORE
ENTER PERIOD T1
⎕:

ENTER PERIOD T2
⎕:
```

FIG. 9: INPUT FORMAT FOR COMPTR

```
PAYGRADE GROUP 2:
OP2 = 1
OP3 = 1
OP5 = 1  1  2  2  3  3  4  4  5  5  6  6  7  7
------------------------------------------------------------------------------------------
TOUR LENGTH              4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20

SEA      TO SHORE       17 12  8  5  0  0  0  0  0  0  0  0  0  0  0  0  0     0
NEUTRAL  TO SHORE        3  3  2  1  0  0  0  0  0  0  0  0  0  0  0  0  0     0

FOR EACH INDICATED ROTATION TYPE,THE CHANGE IN TOTAL PERSONNEL AT SHORE IN
PERIOD 2 DUE TO AN ALTERED ROTATION TYPE VECTOR R IN PERIOD 0 IS
            E-+/RxA
WHERE A IS THE VECTOR CONSISTING OF THE FIRST 17 ENTRIES AND E IS THE
THE LAST ENTRY IN THE ROW CORRESPONDING TO THE ROTATION TYPE
```

FIG. 10: OUTPUT OF COMPTR

is the number of people who came from sea in period 0 and are scheduled to rotate from shore in period 2 - in this example it is 0. If, for example, the sea-to-shore rotation pattern for period 0 is changed so that 5 percent are given a tour length of 7 quarters while the remaining 95 percent are sent to a tour length of 6 quarters, then the consequent change in the shore level is computed as described in the APL expression in figure 10:

$$0 - (.95 \times 8 + .05 \times 5) \approx - 8.$$

That is, this change in the sea-to-shore rotation at period 0 will cause a decrease of approximately 8 people in the shore level in period 2.

The use of COMPTR will be illustrated further in chapter VI.

FILL

The operation of READFILE, WRITEFILE and TRANSFER require the data files to be filled with the appropriately shaped data arrays described in chapter III. Therefore when the files are initially being set up, the components are first filled with shaped 0-arrays. Once this is done, functions using WRITEFILE as a subroutine can be used to automatically load input data. The data files are filled with shaped 0-arrays by typing FILL. In response to the prompt, the user specifies the compartment in which the 0-arrays are to be placed. FILL also initializes the check parameters. (The initial values of the check parameters will be discussed in detail in the description of the CHECK function.)

The user may, of course, develop programs for loading the data files which would directly incorporate FILL or obviate its use altogether.

PRINT

One of the major programs in ROTATIONMOD is the print function which provides access to all the data types listed at the beginning of chapter III. We will first describe in general terms how the user operates PRINT; then specific input/output formats will be illustrated.

The print program has the modular structure described in figure 1. Each data type is printed by a function called PRINTT which is stored in the appropriate component of MOD (the component corresponding to a given data type can easily be determined from the listing of PRINT in appendix B).

The user types PRINT 'DATA TYPE', where DATA TYPE is one of those listed in table 3. In response to the prompts, desired paygrade groups and time periods are entered as numeric vectors. Certain data types will also require the further specification of a duty-type and/or whether the output will be in the form of an array or as totals. After the requested duty type has been printed, a prompt will ask if the user desires to see another duty type. If so, the user responds by typing yes and then specifying the duty type. Otherwise he types no and the program will continue to the next time period or paygrade group. The program can be terminated at any stage where input is requested by typing →. Figure 11 illustrates these possibilities.

Additive data (see table 2) can be aggregated by use of the parameters OP5, which defines paygrade groups, and OP6, which defines groupings of LOS categories. For example, if OP6 = 1, $\underline{L}$ data from all LOS categories are combined. In conjunction with this value of OP6, inventory arrays would be printed as a distribution by tour lengths as illustrated in figure 12.

We shall now describe input/output formats for each of the data types in table 2. The upper portion of figure 13 shows the input format for billet data. The lower portion is output. Since BILLETS is an additive data type, the current workspace value of OP5 is printed out. This defines the paygrade groups to which the output refers. In this example the number of billets for each duty type is the same for each of the time periods $0 \leq T \leq 4$.

PAYGRADE LIMITS are shown in the sample output in figure 14.

Data for PROMOTION PROBABILITIES, ELIGIBLE PROBABILITIES, CONTINUATION, and ADJUSTED PROBABILITIES have the output format illustrated for continuaion in figure 15. Since these are not additive data types, the output format does not include the values of OP5 or OP6. The rows correspond to LOS categories, and the columns correspond to paygrades. In the example, the LOS 8 continuation rate for paygrade group 2 is 0.8718. That is, in paygrade 2 approximately 87 percent of this LOS continue from time period 3 to period 4.

Early rotation data is displayed in figure 16. In this example, for paygrade 3, 2.42 percent of the personnel on shore duty rotate early to sea duty in period 0.

An example of the normal rotation pattern for paygrade 2, in time period 1, is shown in figure 17. In this illustration almost 90 percent of the personnel rotating from shore to sea will be sent to a tour length of 16 quarters.

A typical late rotation pattern is shown in figure 18 for paygrade 3 in time period 0. In this case, 9.4 percent of the sea

```
          PRINT'INVENTORY'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
          0
PAYGRADE GROUPS:1 3
TIME PERIODS:0 1
TOTALS OR ARRAY? ARRAY
DUTY TYPE: SEA
```

.
.
.

(Sea array for paygrade 1 in period 0)

.
.
.

```
DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE PROCEEDING
TO THE NEXT PAYGRADE/TIME PERIOD? YES
DUTY TYPE: SHORE
```

.
.
.

(Shore array for paygrade 1 in period 0)

.
.
.

```
DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE PROCEEDING
TO THE NEXT PAYGRADE/TIME PERIOD? NO
```

.
.
.

(Sea array for paygrade 1 in period 1)

.
.
.

FIG. 11: EXAMPLE OF PRINT SYNTAX

```
      PRINT'INVENTORY'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
      0
PAYGRADE GROUPS:1
TIME PERIODS:0
TOTALS OR ARRAY? ARRAY
DUTY TYPE: SEA


INVENTORY FOR PAYGRADE GROUP =  1
IN PERIOD =  0
(OP5=1  1  2  2  3  3  4  4  5  5  6  6  7  7)
(OP6=1  31)

     SEA

TL =          1         2         3         4         5         6         7         8         9        10        11
         12        13        14        15        16        17        18        19        20

LOSG= 1          1.00      8.00     16.00     27.00     37.00     79.00     75.00    125.00    238.00    260.00    312.00
       189.00    374.00    333.00    187.00      0.00      0.00      0.00      1.00      1.00
```

FIG. 12: DISTRIBUTION OF PAYGRADE BY PRD

```
     PRINT'BILLETS'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
     1
PAYGRADE GROUPS:1
TIME PERIODS:0 1 2 3 4

BILLET REQUIREMENTS FOR PAYGRADE GROUP =  1
(OPS=1  1  2  2  3  3  4  4  5  5  6  6  7  7)

DUTY TYPE:                 SEA              SHORE             NEUTRAL

TM = 0                    2443               645                  13
TM = 1                    2443               645                  13
TM = 2                    2443               645                  13
TM = 3                    2443               645                  13
TM = 4                    2443               645                  13
```

FIG. 13: BILLET OUTPUT OR PRINT

```
     PRINT'PAYGRADE LIMITS'
SPECIFY DATA COMPARTMENT(0 OR 1)
□:
     0
PAYGRADE GROUPS:1 2 3 5
TIME PERIODS:0 1 2 3 4
```

```
PAYGRADE GROUP LIMITS
(OPS=1  1  2  2  3  3  4  4  5  5  6  6  7  7)

PGG=              1        2        3        5

TM = 0         2645     1882     2325      703
TM = 1         2645     1882     2325      703
TM = 2         2645     1882     2325      703
TM = 3         2645     1882     2325      703
TM = 4         2645     1882     2325      703
```

FIG. 14: PAYGRADE LIMITS OUTPUT OF PRINT

```
     PRINT'CONTINUATION'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
     0
PAYGRADES:1 2 3
TIME PERIODS:3
DUTY TYPE: SEA

CONTINUATION RATES FOR PERIOD =   3
DUTY-TYPE:SEA
```

PG =	1	2	3
LOS = 1	0.9074	1.0000	0.5000
LOS = 2	0.8384	0.8269	0.8182
LOS = 3	0.8088	0.7581	0.9730
LOS = 4	0.0860	0.2605	0.5392
LOS = 5	0.5000	0.8704	0.8908
LOS = 6	0.8000	0.8243	0.9013
LOS = 7	1.0000	0.8197	0.9252
LOS = 8	0.0000	$\boxed{0.8718}$	0.8483
LOS = 9	0.0000	0.7273	0.9189
LOS = 10	0.0000	1.0000	0.9231
LOS = 11	0.0000	1.0000	0.9038
LOS = 12	0.0000	0.8333	0.9818
LOS = 13	1.0000	1.0000	0.9143
LOS = 14	0.0000	1.0000	0.9091
LOS = 15	0.0000	1.0000	0.9600
LOS = 16	0.0000	1.0000	0.9677
LOS = 17	0.0000	1.0000	1.0000
LOS = 18	0.0000	0.0000	1.0000
LOS = 19	0.0000	0.0000	0.7500
LOS = 20	0.0000	0.0000	0.0000
LOS = 21	0.0000	0.0000	0.0000
LOS = 22	0.0000	0.0000	0.0000
LOS = 23	0.0000	0.0000	0.5000
LOS = 24	0.0000	0.0000	0.0000
LOS = 25	0.0000	0.0000	0.0000
LOS = 26	0.0000	0.0000	0.0000
LOS = 27	0.0000	0.0000	0.0000
LOS = 28	0.0000	0.0000	0.0000
LOS = 29	0.0000	0.0000	0.0000
LOS = 30	0.0000	0.0000	0.0000
LOS = 31	0.0000	0.0000	0.0000

FIG. 15: CONTINUATION OUTPUT OF PRINT

```
PRINT'EARLY ROTATION'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
     0
PAYGRADES:1 2 3 6 7
TIME PERIODS:0
```

EARLY ROTATION IN PERIOD = 0

ROTATION:	SE→SH	SE→NT	SH→SE	SH→NT	NT→SE	NT→SH
PG = 1	0.0573	0.0013	0.1471	0.0000	0.0000	0.0000
PG = 2	0.1252	0.0000	0.0737	0.0046	0.0000	0.5000
PG = 3	0.0735	0.0000	$\boxed{0.0242}$	0.0000	1.0000	1.0000
PG = 6	0.1190	0.0000	0.0182	0.0000	1.0000	0.0000
PG = 7	0.2857	0.0000	0.0370	0.0000	1.0000	1.0000

FIG. 16: EARLY ROTATION OUTPUT OF PRINT

```
PRINT'NORMAL ROTATION'
SPECIFY DATA COMPARTMENT(0 OR 1)
□:
      0
PAYGRADES:2
TIME PERIODS:1
```

NORMAL ROTATION FOR PAYGRADE PG = 2 IN PERIOD TM = 1

ROTATION:	SE→SH	SE→NT	SH→SE	SH→NT	NT→SE	NT→SH
TL = 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 6	0.0100	0.0000	0.0000	0.0000	0.0000	0.0050
TL = 7	0.0400	0.0000	0.0000	0.0000	0.0000	0.0200
TL = 8	0.8991	0.0009	0.0000	0.0009	0.0000	0.4500
TL = 9	0.0400	0.0000	0.0000	0.0000	0.0000	0.0200
TL = 10	0.0100	0.0000	0.0000	0.0000	0.0000	0.0050
TL = 11	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 13	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 14	0.0000	0.0000	0.0100	0.0000	0.0050	0.0000
TL = 15	0.0000	0.0000	0.0400	0.0000	0.0200	0.0000
TL = 16	0.0000	0.0000	$\boxed{0.8991}$	0.0000	0.4500	0.0000
TL = 17	0.0000	0.0000	0.0400	0.0000	0.0200	0.0000
TL = 18	0.0000	0.0000	0.0100	0.0000	0.0050	0.0000
TL = 19	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TL = 20	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FIG. 17: NORMAL ROTATION OUTPUT OF PRINT

```
     PRINT'LATE ROTATION'
SPECIFY DATA COMPARTMENT(0 OR 1)
⎕:
     0
PAYGRADES:3
TIME PERIODS:0
```

LATE ROTATION FOR PAYGRADE PG = 3 IN PERIOD TM = 0

DUTY TYPE:	SEA	SHORE	NEUTRAL
TL = 1	0.0000	0.0000	0.0000
TL = 2	0.0000	0.0000	0.0000
TL = 3	0.0000	0.0000	0.0000
TL = 4	0.0000	0.0000	0.0000
TL = 5	$\boxed{0.0940}$	0.1040	0.0000
TL = 6	0.0030	0.0270	0.0000
TL = 7	0.0140	0.0130	0.0000
TL = 8	0.0070	0.0100	0.0000
TL = 9	0.0100	0.0370	0.0000
TL = 10	0.0000	0.0070	0.0000
TL = 11	0.0030	0.0030	0.0000
TL = 12	0.0000	0.0030	0.0000
TL = 13	0.0030	0.0000	0.0000
TL = 14	0.0000	0.0130	0.0000
TL = 15	0.0030	0.0030	0.0000
TL = 16	0.0000	0.0030	0.0000
TL = 17	0.0000	0.0000	0.0000
TL = 18	0.0000	0.0000	0.0000
TL = 19	0.0000	0.0000	0.0000
TL = 20	0.0000	0.0000	0.0000

FIG. 18: LATE ROTATION OUTPUT OF PRINT

inventory normally scheduled to rotate in this period will have their PRD's increased to 5 additional quarters.

The data types INVENTORY, ACCESSIONS, PROMOTIONS, SURVIVING INVENTORY, and PREPARED INVENTORY all have the same output format. There are two types of output available for these data types: the matrix array corresponding to a duty type, and the total of this array. An example of the "totals" format is shown in figure 19. The total for each duty type is broken out into rotating and non-rotating totals.

Hence, in this instance, the model has projected a total of 1447 personnel in paygrade 3 at sea in period 2, and 427 of these will rotate to a new duty type during the period.

The final output format is associated with summary data, and is shown in figure 20. These are paygrade totals. All of this data is additive, and the last column indicates aggregate data for the whole rating. Note that the "promotion into" row is zero. This corresponds to the fact that, by definition, there are no promotions into a rating.

PROJECT

This is the main program in ROTATIONMOD. Its purpose is to project the inventory at the beginning of period T - 1 to the beginning of period T. The user simply types PROJECT T. However, several conditions must be satisfied:

- $< T \leq \underline{T}$
- The inventory has been projected to period T - 1
- Adjusted promotion probabilities for period T - 1 have been computed
- Subsequent to projection and computation of adjusted probabilities, no input data for periods $\leq$ T - 1 have been altered.

Violation of any of these conditions results in an error message and termination of the program.

The inventory is projected by the sequence of steps shown in figure 21. This loop is repeated for each paygrade.

The output of PROJECT T is of two types: inventory data and summary data. Normally, when OP4[1] = 0, this data is stored in the period T space in FILE4, as we have previously described in chapter II. However, if OP4[1]=1, PROJECT is modified to read

```
      PRINT 'INVENTORY'
SPECIFY DATA COMPARTMENT(0 OR 1)
D:
      0
PAYGRADE GROUPS:1 3
TIME PERIODS:0 2 3
TOTALS OR ARRAY? TOTALS

TOTAL  INVENTORY FOR PAYGRADE GROUP =  1
(OPS=1   1   2   2   3   3   4   4   5   5   6   6   7   7)

DUTY TYPE:                       SEA                      SHORE                    NEUTRAL

TM = 0         86     2854     2940     319     282     601      7      8     15
TM = 2         11     2220     2232     225     395     620      6      5     11
TM = 3          7     2050     2057     238     346     584      7      4     11


TOTAL  INVENTORY FOR PAYGRADE GROUP =  3
(OPS=1   1   2   2   3   3   4   4   5   5   6   6   7   7)

DUTY TYPE:                       SEA                      SHORE                    NEUTRAL

TM = 0        334      967     1301     390     398     788      1      1      2
TM = 2        427     1020     1447     424     448     872      1      3      4
TM = 3        444     1010     1454     435     432     867      1      3      3
```

FIG. 19: INVENTORY OUTPUT OF PRINT

```
     PRINT'SUMMARY'
SPECIFY DATA COMPARTMENT(0 OR 1)
□:
     0
TIME PERIODS:0


(OP5=1  1  2  2  3  3  4  4  5  5  6  6  7  7)

PAYGRADE GROUP                            1     2     3     4     5     6     7
INITIAL INVENTORY FOR PERIOD     0     3556  2048  2091  1586   714   178    91      10264
INVENTORY AFTER ATTRITION              2705  1232  1815  1435   609   150    75       8021
PROMOTIONS INTO PAYGRADE GROUP            0  1502   859   441   166    68     9          0
ACCESSIONS INTO PAYGRADE GROUP         1724     7    34    54   ¯4      1   ¯1       1815
PAYGRADE GROUP LIMITS FOR PERIOD 1     2645  1882  2325  1842   703   220    83       9700
PROJECTED INVENTORY FOR PERIOD   1     2927  1882  2267  1764   703   210    83       9836
```

FIG. 20: SUMMARY DATA

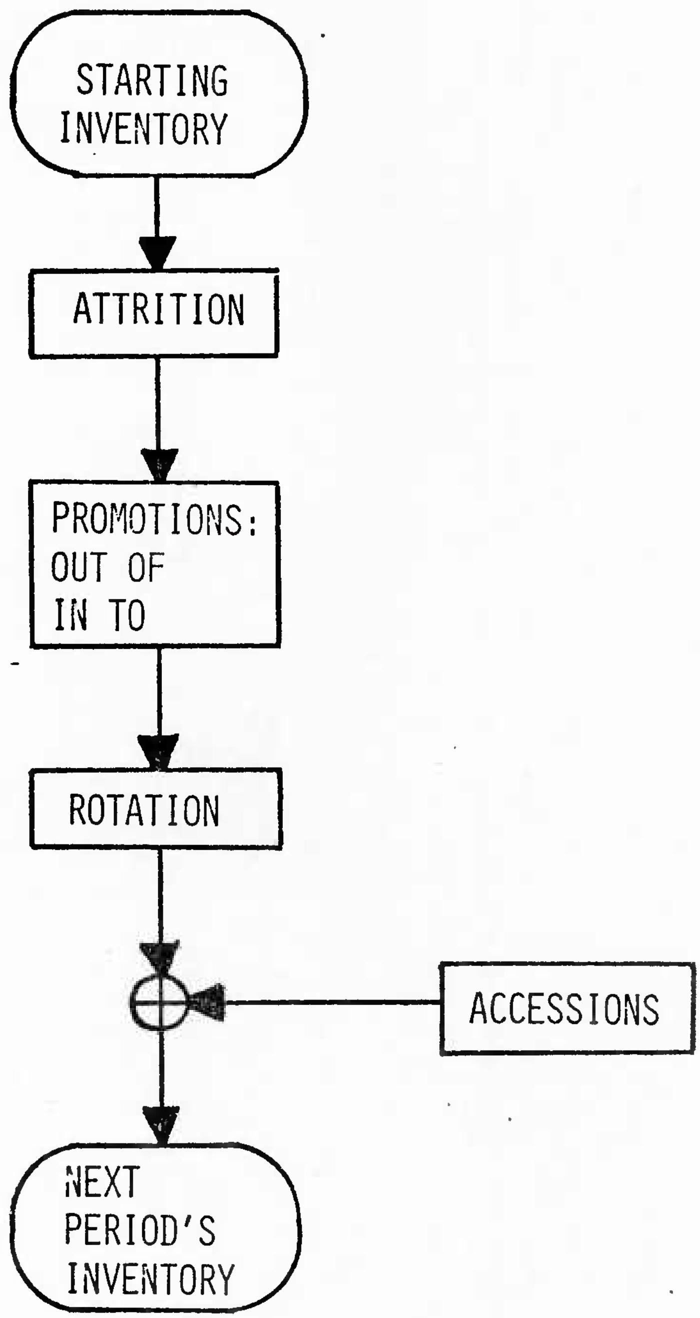


FIG. 21: STEPS IN PROJECT

inventory data from the space corresponding to time period = OP4[2] and its other input data from the space corresponding to a time period = OP4[2] - 1. The inventory which is projected on the basis of this input is stored in the space corresponding to time period = OP4[2], destroying previous stored data. By setting OP4 ← 1, T the user can thus project the inventory stored in the time period T space (using constant input data from the time period T-1 space) to any number of future periods. Since inventories from intervening periods are destroyed in this process, the operator should obtain a hard copy printout of all desired information before proceeding to the next projection. Circumstances in which this option are useful will be described in chapter VI.

The settings of OP2 and OP3 determine which combination of the three rotation categories

- Early rotation (OP3 = 1)
- Normal rotation
- Late rotation (OP2 = 1)

the projection program utilizes (see chapter IV for a discussion of the parameters OP2 and OP3). The setting of OP1 determines the data compartment that PROJECT reads from.

STATUS

When the user types STATUS, current values of all parameters are displayed as shown in figure 22. The interpretation of the display below the dotted line has already been discussed in chapter IV in conjunction with the check parameters.

TRANSFER

This function is used to transfer specified data types from one data file compartment to another. The user types TRANSFER, then indicates to which compartment data is to be transferred. The user also has the option of transfering an entire data file or a specific data type.

In order for this function to work, the data files must be filled with the shaped data arrays described in chapter III.

READFILE and WRITEFILE

These two functions are the primary means of access to the data files. As such, they appear as subroutines in many of the other ROTATIONMOD functions. These two functions manipulate the data units which were defined in chapter III. The syntax of both

```
     STATUS
K = 7                                   OP2 = 1
L = 31                                  OP3 = 1
M = 20                                    I = 5
OP1 = 0

OP4 = 0   0
OP5 = 1   1   2   2   3   3   4   4   5   5   6   6   7   7
OP6 = 1   1   2   2   3   3   4   4   5   5   6   6   7   7   8   8   9
     9   10   10   11   11   12   12   13   13   14   14   15   15
     16   16   17   17   18   18   19   19   20   20   21   21   22
     22   23   23   24   24   25   25   26   26   27   27   28   28
     29   29   30   30   31   31

---------------------------------------------

 TM = 0   1   2   3   4   5

COA = 1   1   0   0   0
COP = 1   1   0   0   0   0

C1A = 0   1
C1P = 0   0
```

FIG. 22: STATUS OUTPUT

functions are the same. The user types READFILE X, where X is a vector whose 4-components specify a file compartment, a data type, a paygrade and a time period respectively ($1 \leq X[2] \leq 12$), where the value of X[2] defines the data type as indicated in table 2. The data unit specified by X is read from the data file and placed in the workspace. Similarly, WRITEFILE X stores the data unit corresponding to X[2] in the file space defined by the coordinates X[1], X[3] and X[4]. If the corresponding data unit is not in the workspace an error results and WRITEFILE is suspended. These functions can be used as subroutines to functions for automatically loading or altering the data base, or the user may apply them directly.

This completes our description of the user oriented functions. Unless it is desired to make alterations in the model, it is not necessary to be familiar with the "system" functions described in the next section.

System Functions

These functions occur as subroutines in the user-oriented programs previously described. They are generally more technical than the user-oriented functions, and so we adopt a more symbolic description throughout this section.

ALTER

Syntax: J ALTER X

J is an integer in the interval $a \leq J \leq 6$. X is a 3-component vector specifying a data compartment, paygrade and time period. The output, a 3-dimentional array called HOLD, is one of the following data-types:

- (J = 1) The inventory array specified by X.
- (J = 2) The late rotating portion of the inventory reassigned to their new tour length cells.
- (J = 3) The normal inventory after late rotating personnel have been removed.
- (J = 4 or 5) The portion of the inventory subject to early rotation.
- (J = 6) Normal inventory after early rotating personnel have been removed.

For J = 2, ALTER produces an array of the same dimensions as inventory. The (a, b, c)-th component is the total number of personnel in duty type a and LOS b who have been ressigned to a new tour length c. The early rotating portion of the inventory is distributed equally in tour length components 1 through 4. Since there are 6 rotation types (see chapter III), the early rotating inventory is further divided into two 3-dimensional arrays, one corresponding to J = 4, and the other corresponding to J = 5. For J = 4 the (a, b, c)-th entry is the total number of early rotating personnel in LOS b with tour length c ($1 \leq c \leq 4$) whose rotation type is 2a-1 (see page 14). For J = 5, the first component a of the HOLD array specifies early rotation type 2a. This division was made in order to avoid output arrays of more than 3-dimensions.

ALTER is used as a subroutine in PREPINV to separate (according to the particular settings of OP2 and OP3) the inventory array into early, normal and late rotating components.

ATTRITION

Syntax: ATTRITION X.

X is the same vector as in ALTER. If OP4[1] = 0, this function applies the appropriate continuation rates to the inventory specified by X, and produces a new inventory consisting of the survivors in each cell (duty-type, LOS, tour length). When OP4[1] = 1, the normal operation of attrition is altered so that it computes a surviving inventory based on the X[3] + 1 time period inventory but using X[3] period continuation rates.

The function is a subroutine of ADJPROB, PROJECT and ALTER.

CHECK

Syntax: X CHECK Z

X is a binary digit, and Z is a 2-component vector. CHECK is a regulatory function which appears in ADJPROB and PROJECT. It serves two purposes. When X = 0, the CHECK routine determines whether the check parameter C0A, C1A, C0P or C1P, which is specified by Z[1] = 1, 2, 3, or 4, respectively, has a non-zero entry in its first Z[2] components (i.e., whether these input data files have been altered since the last projection). When X = 0 CHECK has an output CH. If data has been altered, CH = 0 and CHECK gives an error message. Otherwise CH = 1.

When X = 1, CHECK defines the 0-component check parameter corresponding to Z[1] for time period Z[2] (see chapter IV), and stores it in the data files.

FFF

Syntax: FFF

This function is a subroutine of ADJPROB; it does the computation of adjusted probabilities. Paygrade limits and available positions, computed by ADJPROB, are inputs to FFF. The basis for this computation is described in appendix A.

FILEALT

Syntax: X FILEALT T

X is a 2-component binary vector, T is the time period in which an alteration in file data is to be made. The function FILEALT is designed to be a subroutine in any program (e.g. CHANGE) which alters data file contents. Its effect is to place a 1 in component T + 1 of the check parameter defined by X as shown in figure 23.

x		Check parameter
0	0	C0A
0	1	C0P
1	0	C1A
1	1	C1P

FIG. 23: DETERMINATION OF CHECK PARAMETERS IN FILEALT

GROUP

Syntax: OP6 GROUP X.

Here X is a 4-component vector specifying a data compartment, data type, a paygrade group, as determined by the current value of OP5 (explained in chapter IV), and a time period.

GROUP is a subroutine in those print functions corresponding to additive data types. It aggregates the appropriate data for the paygrade groups or LOS groups defined by OP5 and OP6.

HEADER

Syntax: HEADER I

I is a positive integer in $1 \leq I \leq 6$.

HEADER is a function which prompts the user to specify input data; the type of data depends on the index I as shown in figure 24. When I = 1, the user is asked to respond with a data

I	Prompt
1	DATA TYPE:
2	DUTY TYPE:
3	PAYGRADES:
4	PAYGRADE GROUPS:
5	TIME PERIODS:
6	TOTALS OR ARRAY?

FIG. 24: INDICES FOR HEADER

type; when I = 2 the user must respond with a duty type; when I = 3, a rotation type is required (see page 15); for I = 4, paygrade groups must be described by a numeric vector; I = 5 requires the same response for time periods; and when I = 6, the user response is "totals" or "array." An alternative response to all of these prompts is to type "→", and this will terminate the program in which HEADER is embedded. The output of HEADER is an integer BR in the range $0 \leq BR \leq 3$ whose value is interpreted as follows:

- (BR = 0) Invalid user input. In this case an error message results, and the program in which HEADER is embedded is terminated.

- (BR = 1) This is in response to "→", and indicates termination of the program in which HEADER is embedded.

- (BR = 3) This value occurs when the user has entered a valid input response and signals the beginning of the function in which HEADER is embedded. (Note: at one point in the development of the model the value BR = 2 was used. Subsequent changes rendered this case unnecessary.)

HEADER 6 translates the user's response into a binary digit H, where

$$H = \begin{cases} 0 & \text{if user enters totals} \\ 1 & \text{if user enters array} \end{cases}$$

The print functions in which HEADER 6 occur use the value of H to decide whether to print arrays or totals.

The reason for introducing the variable BR is as follows. Normally, because of the structure of PRINT, if the user terminates the program before completion this will leave a PRINTT function in the workspace which must be expunged before PRINT can be used again. The introduction of the variable BR allows the user to terminate in response to any HEADER prompt without encountering this difficulty. For when BR = 1, PRINTT will branch to its last step and is automatically expunged by the calling program.

PREPINV

Syntax: PREPINV X

X is the same vector as in ALTER.

PREPINV is a subroutine of PROJECT and GROUP, whose function is to prepare the inventory for rotation. First, the specified inventory is subjected to attrition; then, according to the settings of OP2 and OP3, the surviving inventory is divided into early and normally rotating components (the late rotating component after being assigned to new tour length positions is added to the normal inventory). Finally, for each of these components, promotions into and out of the paygrade are computed and a new inventory (still separated into two components) after promotions is the result. This "prepared" inventory is ready to be rotated.

Because of workspace limitations, the prepared inventory arrays defined by PREPINV are represented by a (0, 1)-array and a vector whose components are the non-zero entries of the array (this decomposition has already been described in chapter III).

PRIN

Syntax: I PRIN X

I is either 1 or 2, and X is a data array.

PRIN is a format function which appears in PRINT. Its purpose is to format the output of the various PRINTT functions.

This completes our discussion of the structure of ROTATIONMOD. In the next chapter some general principles for operating the model are described.

CHAPTER VI

USING ROTATIONMOD

Chapter I consists of a general description of the expanded rotation model and its characteristics. In this chapter those remarks will be amplified and extended, and a sample analysis will be presented. Although a detailed knowledge of APL is not required for operation of the model, it is assumed that the user is familiar with APL notation and the management of APL workspaces.

Applications of the model include:

- projecting current inventory to a five year horizon

- determining what alterations in accessions and rotation policies will provide desired paygrade endstrengths and sea/shore distributions of personnel throughout the five year projection period

- using this projection as a baseline to modify controllable manpower variables to produce a desired inventory profile

- detecting changes in uncontrollable variables by comparison of actual and projected inventories

- answering "what if" questions.

The variables which influence the five year projections are endstrength requirements, accessions, continuation rates and promotions; however, the variables which can be manipulated by the user (within real-world constraints of course) are generally limited to accessions, and rotation. Although incentives of various sorts may influence continuation, the Navy cannot affect it very much. Moreover, the relations between continuation and factors which influence it are not well understood in any quantitative sense. Endstrength requirements are pretty well determined, and the computation of adjusted promotion probabilities is built into the model.

Substantial changes in either early or late rotation will result in increased personnel costs and are disruptive to both morale and the stability of sea/shore distributions. Thus systematic manipulation of these variables would not be desirable. The role of early and late rotation in the modeling process should be restricted to accounting for PRD changes due to unavoidable factors, such as operational holds, humanitarian considerations, leave between duty tours, and participation in schools.

Once a suitable inventory profile has been projected, by appropriately altering accessions and rotation patterns as necessary, the data base which corresponds to this profile can be used as a guide to ERCs and detailers in making actual personnel assignments. To the extent that practice conforms to the policies described in the data base, the real-world personnel distribution will reflect the desirable characteristics of the projection.

The first step in using ROTATIONMOD is to define the parameters $\underline{K}$, $\underline{L}$, $\underline{M}$, and $\underline{T}$. These should be saved in the workspace, and they remain fixed throughout the entire analysis of the particular community or rating being considered. Normally $\underline{K} = 7$ (there are nine paygrades, but the first three are usually not distinguished), $\underline{L} = 31$, $\underline{M} = 20$, and $\underline{T} = 5$ (due to file space limitations, larger values of $\underline{T}$ cannot conveniently be accommodated). Next the initial values of the parameters OP1, OP2, OP3, OP4, OP5 and OP6 should be set. These define the normal mode of operation of the functions, and should also be saved in the workspace so that whenever it is loaded, the parameters will be automatically reset to these values. For example, the normal setting for operation of the model would be OP1←0, OP2←Op3←1, OP4←0,0, OP5←1, 1, ... $\underline{K}$, $\underline{K}$ and OP6← 1, 1, ... $\underline{L}$, $\underline{L}$. ROTATIONMOD will then utilize data from the 0-compartment. With the indicated setting of OP2 and OP3, all three types of rotation data will be used in projecting the inventory. The projected inventory for time period T will be based on period T-1 input data. Also, paygrade groups and LOS groups will correspond to the normal paygrades and LOS categories determined by $\underline{K}$ and $\underline{L}$. At all times the user must exercise caution to see that the parameters are appropriately defined for the purpose at hand. Their current values can be checked by typing STATUS.

Using FILL, the following data files can be loaded with appropriately shaped 0-arrays:

- Billets
- Paygrade limits
- Promotion probabilities
- Eligible probabilities
- Continuation
- Early rotation
- Normal rotation
- Late rotation
- Accessions
- Adjusted probabilities
- Inventory
- Summary

After this has been done, programs for automatically loading data by data units, which incorporate the WRITEFILE function, can be used to enter the data base. Alternatively, the user may wish to develop other methods for loading the data files which do not use FILL or the WRITEFILE function.

The data types and their structure have been discussed in chapter III; however, some additional remarks are appropriate here. Historial data for the community under consideration can be obtained from the enlisted master record (EMR). This includes promotion probabilities, "LOS" continuation rates, rotation data, and accessions. Billet requirements are determined by Navy manning policies in conjunction with paygrade endstrength limits imposed by Congress. For data types such as promotion probabilities and continuation it may be useful to use the averaged data from several periods. Eligible probabilities depend on length in service requirements and test scores. When the model was applied to several test communities, eligible probabilities were estimated by taking the maximum value of 1 and 1.5 times the historial probabilities. This gives an eligible probability distribution which is similar to the historial distribution, and at the same time allows the model to respond to alterations in endstrength requirements or changes in other variables which affect promotions.

Initially the same data can be entered for each projection period unless there are specific anticipated (or desired) alterations from period to period; e.g. the user may wish to analyze the effect that a predicted decline in continuation would have on filling sea billets under the present rotation policy.

The inventory is projected to $\underline{T}$ periods by alternately running ADJPROB T and PROJECT (T+1) for T = 0,1, ..., $\underline{T}$-1. When OP4 = 0,0 the results of each projection are stored in the data file in the appropriate time period space. The complete data base, including these projected inventories, can be accessed by the PRINT function. If alterations in input data, such as rotation patterns or accessions, are desired, a copy of the original projection and input data can be transferred to the opposite compartment by using the TRANSFER function. As long as OP1 is not changed, this data will remain intact while the original input can be modified. After changing input data, another projection can be run to see the consequences. Thus an important application of the model is to answer "what if" type questions: what will a 10 percent change in continuation do to the sea/shore distribution; or what are future consequences of changing rotation patterns?

Another important feature of the model lies in its interactive capability, allowing complex interrelations between the data types, and a large number of possible alterations to achieve a given inventory profile. This allows the user to attain desired goals--or determine that they are inconsistent--through a series of iterative steps in which a projection is alternated with selective modification of the data base. The users' knowledge and intuition concerning the sea/shore rotation process will be helpful in deciding what kind of changes are necessary to project a desired result. User-oriented functions, such as COMPTA and COMPTR help the operator estimate the magnitude of required changes.

The parameter OP4 provides the user with a means of extending the projection capability of the model beyond its normal limits. However, when this option is used, each projection destroys the previous inventory so the user must obtain hard copy data from that inventory before proceeding with a further projection. Also, the input data (other than inventory to be projected) cannot be altered for each projection, but must remain independent of time. To use this option the operator sets OP4 $\leftarrow$ 1,T where T is some time period in the interval $1 \leq T \leq \underline{T}$. Then the inventory to be projected is that which is stored in the time period T space, and the remaining input data on which the projection is based (i.e. continuation, rotation, accessions, etc.) is that which is in the T - 1 time period space. For example, the operator may project the inventory normally to $\underline{T}$ periods, then set OP4 $\leftarrow$ 1,$\underline{T}$ and project further to a period T', say, with the limitations of a constant time period $\underline{T}$ - 1 input for each projection and loss of the projected inventories for intervening periods between $\underline{T}$ and T'.

We shall now give an example of the application of ROTATIONMOD. The initial inventory is the SeaBee community in 1976. The other input data was obtained by comparing the 1976 EMR with the 1977 EMR. For the first set of projections, the paygrade limits that were used at each of the five projection periods were simply the paygrade endstrengths in 1976. The results of this initial projection are summarized in figures 25 and 26. Figure 26 shows a more detailed breakdown of the sea/shore distribution for paygrade group 3. From figure 25 we see that the projected SeaBee community will sustain a loss of 1,134 personnel in this 5-year period. By examining more detailed output (indicated here for paygrade group 3) for each paygrade we find that 947 of the losses will be from sea duty. Suppose that it is desired to attain an overall force size of 9,700 within 3 years, with the new paygrade limits indicated in figure 27. By using COMPTA, we obtain an estimate of 1,872 as the number of accessions needed per period over 3 years to attain the desired force level; this requires an increase of 268 per year. Since most accessions come into paygrade group 1, this is where the additional 268 personnel would enter. Using CHANGE, the original accession array for this paygrade can be scaled by an appropriate factor so that the new accessions total is 1,827. There are clearly many other ways of increasing accessions, and each of these will have implications for the sea/shore process. The user must be aware of a variety of options.

After accessions were changed, the inventory was again projected for 3 periods. The rating totals for each of these

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	0	3556	2048	2091	1586	714	178	91	10264
INVENTORY AFTER ATTRITION		2705	1232	1815	1435	609	150	75	8021
PROMOTIONS INTO PAYGRADE GROUP		0	1213	570	294	141	43	9	0
ACCESSIONS INTO PAYGRADE GROUP		1604	7	34	54	¯4	1	¯1	1695
PAYGRADE GROUP LIMITS FOR PERIOD	1	3097	1882	2125	1642	703	185	83	9717
PROJECTED INVENTORY FOR PERIOD	1	3096	1882	2125	1642	703	185	83	9716

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	1	3096	1882	2125	1642	703	185	83	9716
INVENTORY AFTER ATTRITION		2406	1111	1828	1490	606	142	64	7648
PROMOTIONS INTO PAYGRADE GROUP		0	822	409	406	184	68	23	0
ACCESSIONS INTO PAYGRADE GROUP		1604	7	34	54	¯4	1	¯1	1695
PAYGRADE GROUP LIMITS FOR PERIOD	2	2789	1531	1865	1766	718	196	96	8961
PROJECTED INVENTORY FOR PERIOD	2	3188	1531	1865	1766	718	188	86	9343

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	2	3188	1531	1865	1766	718	188	86	9343
INVENTORY AFTER ATTRITION		2552	956	1586	1615	640	151	70	7570
PROMOTIONS INTO PAYGRADE GROUP		0	1511	592	87	114	47	14	0
ACCESSIONS INTO PAYGRADE GROUP		1604	7	34	54	¯4	1	¯1	1695
PAYGRADE GROUP LIMITS FOR PERIOD	3	3097	1882	2125	1642	703	185	83	9717
PROJECTED INVENTORY FOR PERIOD	3	2645	1882	2125	1642	703	185	83	9265

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	3	2645	1882	2125	1642	703	185	83	9265
INVENTORY AFTER ATTRITION		2208	1144	1792	1484	632	154	70	7484
PROMOTIONS INTO PAYGRADE GROUP		0	1253	522	223	119	45	14	0
ACCESSIONS INTO PAYGRADE GROUP		1604	7	34	54	¯4	1	¯1	1695
PAYGRADE GROUP LIMITS FOR PERIOD	4	3097	1882	2125	1642	703	185	83	9717
PROJECTED INVENTORY FOR PERIOD	4	2559	1882	2125	1642	703	185	83	9179

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	4	2559	1882	2125	1642	703	185	83	9179
INVENTORY AFTER ATTRITION		2165	1170	1764	1479	634	152	71	7435
PROMOTIONS INTO PAYGRADE GROUP		0	1226	554	227	118	45	13	0
ACCESSIONS INTO PAYGRADE GROUP		1604	7	34	54	¯4	1	¯1	1695
PAYGRADE GROUP LIMITS FOR PERIOD	5	3097	1882	2125	1642	703	185	83	9717
PROJECTED INVENTORY FOR PERIOD	5	2543	1849	2125	1642	703	185	83	9130

FIG. 25: ORIGINAL SEABEE PROJECTIONS

TOTAL INVENTORY FOR PAYGRADE GROUP = 3
(OPS=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

DUTY TYPE:		SEA			SHORE			NEUTRAL	
TM = 0	334	967	1301	390	398	788	1	1	2
TM = 1	385	933	1318	388	414	803	2	3	5
TM = 2	321	804	1125	372	365	736	1	3	4
TM = 3	382	926	1307	414	400	814	1	3	4
TM = 4	399	922	1321	396	404	801	1	3	4
TM = 5	387	913	1301	405	416	821	1	3	3

FIG. 26: ORIGINAL SEABEE PROJECTIONS FOR PAYGRADE 3

Paygrade	Paygrades						
limits	1	2	3	4	5	6	7
Old	3097	1882	2125	1642	703	185	83
New	2645	1882	2325	1842	703	220	83

FIG. 27: NEW PAYGRADE LIMITS FOR SEABEES

periods are shown in figure 28. At the third period, the projection is very close to the desired goal of 9,700.

Time periods	Rating totals
0	10,264
1	9,893
2	9,674
3	9,721

FIG. 28: SECOND PROJECTION OF SEABEE RATING USING ORIGINAL ENDSTRENGTHS AND ASSESSIONS

In the next step the new paygrade limits were entered and the inventory was again projected to 3 years. The result is shown in figure 29; the new paygrade limits have affected the rough

Time periods	Rating totals
0	10,264
1	9,893
2	9,730
3	9,840

FIG. 29: THIRD PROJECTION OF SEABEE RATING USING NEW ENDSTRENGTHS AND INCREASED ACCESSIONS

estimates of continuation on which the COMPTA calculations are based. Therefore it was necessary to reestimate needed accessions per period and project again. The projection shown in figure 30 is the final result of two iterations of this process. The projection was run twice in order to try to fill paygrade endstrengths in the lower paygrades 1 and 2. However, we were not able to significantly improve the personnel distribution between these paygrades by period 3. The reason is that eligibility limits for paygrade 1 did not allow a sufficient number of promotions into paygrade 2.

In order to simplify the example, we have not taken into account the fact that entries into paygrade 1 must satisfy length of service requirements before becoming eligible for promotion. This would mean that an increase of promotions into paygrade 2 might be delayed 1 or 2 periods.

After having attained a desired endstrength and paygrade distribution at the end of period 3, a similar analysis can be used to stabilize this inventory profile over the remaining two periods if that is desired.

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	0	3556	2048	2091	1586	714	178	91	10264
INVENTORY AFTER ATTRITION		2705	1232	1815	1435	609	150	75	8021
PROMOTIONS INTO PAYGRADE GROUP		0	1502	859	441	166	68	9	0
ACCESSIONS INTO PAYGRADE GROUP		1724	7	34	54	¯4	1	¯1	1815
PAYGRADE GROUP LIMITS FOR PERIOD	1	2645	1882	2325	1842	703	220	83	9700
PROJECTED INVENTORY FOR PERIOD	1	2927	1882	2267	1764	703	210	83	9836

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	1	2927	1882	2267	1764	703	210	83	9836
INVENTORY AFTER ATTRITION		2366	1077	1924	1606	609	161	64	7808
PROMOTIONS INTO PAYGRADE GROUP		0	1376	714	348	166	68	20	0
ACCESSIONS INTO PAYGRADE GROUP		1873	7	34	54	¯4	1	¯1	1964
PAYGRADE GROUP LIMITS FOR PERIOD	2	2645	1882	2325	1842	703	220	83	9700
PROJECTED INVENTORY FOR PERIOD	2	2863	1747	2324	1842	703	210	83	9772

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	2	2863	1747	2324	1842	703	210	83	9772
INVENTORY AFTER ATTRITION		2425	1129	1926	1685	628	169	67	8030
PROMOTIONS INTO PAYGRADE GROUP		0	1350	613	248	146	66	17	0
ACCESSIONS INTO PAYGRADE GROUP		1577	7	34	54	¯4	1	¯1	1668
PAYGRADE GROUP LIMITS FOR PERIOD	3	2645	1882	2325	1842	703	220	83	9700
PROJECTED INVENTORY FOR PERIOD	3	2652	1872	2325	1842	703	220	83	9698

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	3	2652	1872	2325	1842	703	220	83	9698
INVENTORY AFTER ATTRITION		2244	1197	1907	1673	635	184	69	7908
PROMOTIONS INTO PAYGRADE GROUP		0	1286	622	237	122	50	15	0
ACCESSIONS INTO PAYGRADE GROUP		1781	7	34	54	¯4	1	¯1	1872
PAYGRADE GROUP LIMITS FOR PERIOD	4	2645	1882	2325	1842	703	220	83	9700
PROJECTED INVENTORY FOR PERIOD	4	2739	1868	2325	1842	703	220	83	9780

(OP5=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

PAYGRADE GROUP		1	2	3	4	5	6	7	
INITIAL INVENTORY FOR PERIOD	4	2739	1868	2325	1842	703	220	83	9780
INVENTORY AFTER ATTRITION		2323	1162	1891	1666	636	181	70	7929
PROMOTIONS INTO PAYGRADE GROUP		0	1298	644	244	122	51	14	0
ACCESSIONS INTO PAYGRADE GROUP		1679	7	34	54	¯4	1	¯1	1770
PAYGRADE GROUP LIMITS FOR PERIOD	5	2645	1882	2325	1842	703	220	83	9700
PROJECTED INVENTORY FOR PERIOD	5	2704	1823	2325	1842	703	220	83	9699

FIG. 30: FINAL SEABEE PROJECTIONS

The next step in our example is to consider the sea/shore/neutral distribution within paygrades. For purposes of illustration we shall focus on paygrade 3. However, it is essential to note that alterations in the rotation pattern in any paygrade will affect the duty type distribution in higher paygrades because personnel who are promoted retain their PRD's, thus a significant number of promotions out of a paygrade can change the distribution of personnel in the next higher paygrade. The paygrade 3 distribution for the last projection is given in figure 31. This shows a steadily increasing shore contingent. Assume that it is desired to maintain a stable shore total of about 788 (i.e. keep the size of the shore component the same as it is initially). Since the paygrade endstrength has been increased, this will result in more personnel at sea.

TOTAL INVENTORY FOR PAYGRADE GROUP = 3
(OPS=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

DUTY TYPE:	SEA			SHORE			NEUTRAL		
TM = 0	334	967	1301	390	398	788	1	1	2
TM = 1	426	990	1416	417	429	846	2	4	5
TM = 2	427	1020	1447	424	448	872	1	3	4
TM = 3	444	1010	1454	435	432	867	1	3	3
TM = 4	458	988	1447	430	445	875	1	3	4
TM = 5	449	972	1421	442	458	900	1	3	4

FIG. 31: PAYGRADE 3 PROJECTIONS FOR SEABEES USING ORIGINAL NORMAL ROTATION PATTERN

The size of the shore component at any time T > 0 will be affected by two factors: (i) the number of people who are rotating from shore duty in period T - 1, and (ii) the number of people who will be coming to shore in period T. Each of these factors can be influenced by alterations in the rotation pattern. For example in period 1 the table in figure 31 shows an increase of 58 people at shore. Unless existing PRD's are changed, the only way to decrease this number is to send more rotating sea personnel to neutral. Therefore, if neutral duty is to be kept small there is little that can be done to normal rotation patterns that will reduce the size of the shore component in period 1.

At period 2 there is a projected increase of 84 personnel ashore. Now, however, an alteration in the normal rotation pattern in period 0 can reduce this projected increase. The normal sea to shore rotation pattern in period 0 is described below.

tour length (in quarters)	6	7	8	9	10
percent rotated to tour length	.01	.04	.89	.04	.01

FIG. 32: INITIAL SEA TO SHORE ROTATION PATTERN

Thus 89 percent of the rotating sea personnel are sent to shore for a tour length of 8 quarters; in all, 99 percent are sent to shore duty. Using COMPTR with T1 = 0 and T2 = 2 we find that with the current rotation pattern approximately 3 of these people will rotate <u>from</u> shore in period 1. This can be computed from the portion of the COMPTR output table shown in figure 33 using the above rotation pattern.

Tour length	4	5	6	7	...	20
Sea to shore	199	140	89	43	...	3
Neutral to shore	1	1	0	0	...	0

FIG. 33: OUTPUT OF COMPTR FOR T1=0 and T2=2

The entries which are not indicated are all zeros. However, if all 99 percent of the sea to shore rotating personnel are sent to a tour length of 7 quarters then there will be

$$0.99 \times 43 \approx 43$$

people in this group who will rotate from shore in period 1 (see description of COMPTR in chapter IV); therefore in period 2 the shore size will be decreased by approximately

$$43 - 3 = 40.$$

When this alteration in normal rotation is made, and the inventory projected again using the new pattern, the results for paygrade 3 are shown in figure 34.

TOTAL INVENTORY FOR PAYGRADE GROUP = 3
(OPS=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

DUTY TYPE:		SEA			SHORE			NEUTRAL	
TM = 0	334	967	1301	390	398	788	1	1	2
TM = 1	426	990	1416	491	353	844	2	4	5
TM = 2	427	1060	1487	383	447	830	1	3	5
TM = 3	444	1014	1457	429	433	862	1	3	3
TM = 4	459	988	1447	430	444	875	1	3	4
TM = 5	461	960	1421	442	458	900	1	3	4

FIG. 34: PAYGRADE 3 PROJECTION FOR SEABEES USING NEW ROTATION PATTERN IN PERIOD 0

The change in normal rotation has resulted in a smaller increase (≈32) in the shore size in period 2, however there is no substantial effect in later periods.

A more extreme alteration in the normal rotation pattern at period 0 would have resulted in an even better result. For example if .92 ≈ 84/89 of the sea-to-shore rotating personnel are sent to a tour length of 6 quarters, and the remainder are distributed over 7 to 10 quarters then the new projection would have resulted in a shore total of 788 in period 2. The user of the model must decide what alterations in rotation are acceptable.

At period 3 the projected shore size (figure 34) is 74 above the desired level. Using COMPTR with T1 = 1 and T2 = 3 we obtain the output:

Tour length	4	5	6	7 ...	20	
Sea to shore	239	176	114	64 ...	0	4
Neutral to shore	0	0	0	0 ...	0	0

FIG. 35: OUTPUT OF COMPTR WITH T1=1, T2=3

In order to reduce shore size to 788 in period 3 it is not sufficient to send everyone rotating from sea-to-shore in period 1 to a tour length of 7 quarters, as before, since this would result in a decrease of only

$$(.99 \times 64) - 4 \approx 59$$

people. Therefore a reduction in shore size of 74 will require that a certain percentage of personnel rotate to a tour length of 6 quarters at shore. Another possibility is to reduce the number of people coming <u>to</u> shore in period 3. This can be accomplished either by sending a larger percentage of rotating sea personnel to neutral or by extending sea tours. However, in this example the sea tour lengths already average around 16 quarters, so an increase here could have adverse effects on moral and ultimately on continuation. In view of these considerations, the user may decide to solve his problem by decreasing shore tours at period 1.

Assuming this is the case, we want to send a percentage x to 6 quarters and a percentage y to 7 quarters in such a way that (see figure 35)

$$114\,x + 64y = 74$$

and

$$x + y = .99\ .$$

The solution of this system of equations is

$$x = 0.21,\ y = 0.78\ .$$

It is clear that there are many possible rotation patterns that will result in the desired decrease in shore size, the solution given here was motivated by a desire to keep neutral duty the same size (second equation) and reduce the shore tour as little as possible.

Proceeding as above for each succeeding time period we arrive at the following sea to shore rotation pattern for periods T = 0, 1, 2, 3:

Tour length =	6	7
T = 0	0	.99
T = 1	.21	.78
T = 2	.31	.68
T = 3	.79	.20

FIG. 36: ALTERED SEA TO SHORE ROTATION

The inventory which is projected with the new rotation pattern is shown in figure 37. Note from figure 36 that in period

TOTAL INVENTORY FOR PAYGRADE GROUP = 3
(OPS=1 1 2 2 3 3 4 4 5 5 6 6 7 7)

DUTY TYPE:		SEA			SHORE			NEUTRAL	
TM = 0	334	967	1301	390	398	788	1	1	2
TM = 1	426	990	1416	491	353	844	2	4	5
TM = 2	427	1060	1487	505	323	827	1	3	5
TM = 3	444	1084	1528	492	295	787	1	3	4
TM = 4	459	1071	1530	519	263	782	1	3	4
TM = 5	461	1068	1528	526	255	781	1	3	4

FIG. 37: PROJECTION FOR PAYGRADE 3 OF THE SEABEES USING THE NEW NORMAL ROTATION PATTERN

3 a substantially greater percentage of the sea to shore rotating personnel are sent to a short tour length than is the case in earlier periods. The reason is that personnel sent to sea in period 0 are returning to shore in period 5, and therefore the alterations in rotation in period 3 must also compensate for this increased flow.

In order to analyze the effects of the changes that have been made in rotation, the user can set OP4 $\leftarrow$ 1, 5 and project the inventory to period 6 as previously described.

The example given illustrates one aspect of the applicability of the model. ROTATIONMOD can be used for a variety of analyses, and it is anticipated that specialized programs will be written to facilitate these applications. We shall consider one more example. For a given rotation policy (including accessions, continuation and promotion) there are definite steady-state inventories for which that policy can be implemented. Such an inventory can be scaled to any desired size, but the ratios between sea/shore/neutral totals will be determined by the rotation policy. This fact must be taken into account in considering the following question: how many shore billets are needed to support rotation when the number of sea billets is given? In order to answer this, it is first necessary to find a steady-state inventory (computational methods for doing this are discussed in appendix A) with respect to the stated rotation policy. This inventory can be scaled to give the desired number of sea personnel. The corresponding size of the shore contingent will then determine how many shore billets must be bought to support the desired rotation.

REFERENCES

1. Donald Maurer, "Sea/Shore Rotation," Summary Report 7, Unclassified, Center for Naval Analyses, Jun 1979

2. Marc D. Joseph, "The Prophet System for Projection of Inventories in Ratings and Other Subpopulations," Research Contribution 346, Unclassified, Center for Naval Analyses, May 1978

APPENDIX A

DESCRIPTION OF THE EXPANDED ROTATION MODEL

APPENDIX A

DESCRIPTION OF THE EXPANDED ROTATION MODEL

The purpose of this appendix is to describe the theoretical basis for the expanded rotation model (ROTATIONMOD). This will include a discussion of the simplifying assumptions which were used, and estimates of the error which these introduce into the model. The final section deals with several applications of the model.

DESCRIPTION OF THE MODEL

Personnel movements in a rating or group of ratings are modeled as a network with flows. Each node or "cell" in the network is characterized by four components (j, k, ℓ, m), where j designates a paygrade group, k represents one of the duty types, ℓ is a length of service (LOS) category, and m represents the number of quarters until rotation to a new duty type. The parameters $\underline{K}$, $\underline{L}$ and $\underline{M}$ are the maximum values of j, ℓ and m respectively. Since any number of paygrades can be aggregated if desired, $\underline{K}$ is variable. Usually however $\underline{K} = 7$ and the first three paygrades E-1, E-2 and E-3 are aggregated as paygrade group 1. If length of service is measured in years then $\underline{L} = 31$, and periods to rotation are measured in quarters; thus $\underline{M} = 20$ corresponds to a maximum tour length of five years.

There are three types of duty --

(1) sea
(2) shore
(3) neutral.

Therefore the components of a cell are limited by the inequalities

$$(1) \qquad \begin{array}{l} 1 \leq j \leq \underline{K} \\ 1 \leq k \leq 3 \\ 1 \leq \ell \leq \underline{L} \\ 1 \leq m \leq \underline{M} \end{array} \quad .$$

We use $N^t(0;j,k,\ell,m)$ to denote the total number of personnel in cell (j, k, ℓ, m) at the beginning of period t (i.e. all personnel who have the characteristics specified by the coordinates). For convience we also define $N^t(0;j,k,\ell,m) = 0$ whenever one of the coordinates lies outside the range specified in (1).

The only possible flows out of a node are those defined below:

$$
(2)\qquad
\begin{aligned}
(j,k,\ell,m) &\longrightarrow (j,\ k,\ \ell+1,\ m-4) && \text{if } m > 4\\
(j,k,\ell,m) &\longrightarrow (j+1,\ k,\ \ell+1,\ m-4) && \text{if } m > 4\\
(j,k,\ell,m) &\longrightarrow (j,\ k',\ \ell+1,\ m') && \text{if } m \le 4\\
(j,k,\ell,m) &\longrightarrow (j+1,\ k',\ \ell+1,\ m') && \text{if } m \le 4\ .
\end{aligned}
$$

These flows model the several types of personnel movements. When an individuals' projected rotation date (PRD) to another duty type is larger than four quarters, he normally remains in the same duty type until next period, but his PRD is decreased by four, and his LOS is increased by one. The first two expressions represent this type of flow. In the second expression the individual has been promoted to the next higher paygrade. In (2) $k' \neq k$ and the flows involving k' represent actual changes in duty type. As before, flows of the form $(j, ., ., .) \rightarrow (j+1, ., ., .)$ represent promotions into the next higher paygrade. These restricted flows are based on certain assumptions concerning the personnel process; for instance, that an individuals' tour length is <u>not</u> altered once he has been assigned to a duty type. This is not strictly true, and in some ratings a substantial portion of the inventory experience alterations in tour lengths. At a later stage, we will introduce procedures for altering this "normal" rotation pattern. Another assumption that is implied by (2) is that no one is promoted more than one paygrade per period. This is essentially true. Finally relations (2) imply that an individual who is promoted will remain in the same (k, ℓ, m)-th cell; that is, time remaining in duty type is not affected by promotion.

In addition to the flows which have been described thus far, there are flows into and out of the network which represent positive or negative accessions. Positive accessions are personnel added to the rating--either new enlistees or lateral transfers; negative accessions are losses to the inventory due to factors such as a lateral transfer out of the rating. Also, school candidates are not part of the distributable inventory. This can be modeled by considering them as negative accessions to the rating when they go into school, and positive accessions when they finish school and are again counted as distributable. We use the notation $A^t(j,k,\ell,m)$ to represent total accessions to cell (j,k,ℓ,m), i.e. the difference between positive and negative accessions.

The inventory at the beginning of period t+1 is given by the equations

$$N^{t+1}(0;j,k,\ell,m) = A^t(j,k,\ell,m) + \text{(inflows from promotions and rotation in period t)}.$$

We shall describe the second term in this relation more precisely; the exact form which it takes will depend upon attrition, promotions and rotation policies. Attrition in period t is modeled by an $\underline{L}$ - component vector γ_{jk}^{t} for each paygrade j and duty type k. The ℓ-th component γ_{jk}^{t} is the fraction of personnel in the (j,k,ℓ)-th cell who remain in the Navy throughout period t. It is then assumed that

$$(3) \qquad N^{t}(1;j,k,\ell,m) = \gamma_{jk\ell}^{t} \cdot N^{t}(0;j,k,\ell,m)$$

is the percentage of the (j,k,ℓ,m)-th cell which remains in the Navy throughout the t-th period.

Promotions are modeled in a similar fashion by $\underline{L}$-component vectors ϱ_{jk}^{t}; and it is assumed that

$$\varrho_{jk\ell}^{t} \cdot N^{t}(1;j,k,\ell,m)$$

of the survivors in cell (j,k,ℓ,m) are promoted. Thus this cell contains

$$(4) \qquad N^{t}(2;j,k,\ell,m) = (1-\varrho^{t}{jk\ell}) \cdot N^{t}(1;j,k,\ell,m)$$

personnel after promotions.

The promotion vectors are "adjusted" each period to reflect changes in accessions, continuation or endstrength requirements. This adjustment essentially consists of scaling fixed input vectors ϱ_{jk} of historical promotion probabilities. The components of ϱ_{jk} are historical promotion probabilities averaged over past periods. Since there are definite requirements, such as length in service and test passing, that must be satisfied before an individual is eligible for promotion, not everyone in a paygrade or LOS category can be promoted. The percentage of individuals in each LOS who are eligible for promotion are described by $\underline{L}$-component vectors ϵ_{jk} in which the ℓ-th component $\epsilon_{jk\ell}$ is the fraction of the (j,k,ℓ)-th cell which is eligible to be promoted. Thus at each period t we must have

$$\varrho_{jk\ell} \leq \varrho_{jk\ell}^{t} \leq \epsilon_{jk\ell} \text{ for all } j,k,\ell \ .$$

The explicit determination of ϱ_{jk}^{t} proceeds as follows. First the available positions in paygrade j+1 are computed by the equation

$$\alpha^t_{j+1} = \max(0,\ E^t_{j+1} - S^t_{j+1} + P^t_{j+1} - A^t_{j+1})$$

where E^t_j is the desired paygrade endstrength in period t, S^t_j is the total surviving inventory, P^t_j is the total number of promotions out of paygrade j ($P^t_{\underline{K}} = 0$), and A^t_j is the total accessions to paygrade j. Now let the vector δ_{jk} be defined component-wise by $\delta_{jk\ell} = \min(\varrho_{jk\ell}, \epsilon_{jk\ell})$ for each ℓ, and set

$$P_j = \sum_{k,\ell} \delta_{jk\ell} \sum_m N^t(1;j,k,\ell,m).$$

We consider two cases:

Case 1. $P_j > \alpha^t_{j+1}$.

In this case it is necessary to promote fewer people than the "normal" promotion vectors δ_{jk} specify. Therefore we define ϱ^t_{jk} by

$$\varrho^t_{jk} = \omega \bullet \delta_{jk}\ , \text{ where } \omega = \alpha^t_{j+1}/P_j \quad .$$

Case 2. $P_j \leq \alpha^t_{j+1}$.

In this case we must promote more people than the normal promotion vectors δ_{jk} specify. We therefore define ϱ^t_{jk} as a <u>weighted</u> <u>average</u> of δ_{jk} and ϵ_{jk}:

(5) $$\varrho^t_{jk} = (1-\omega)\bullet\delta_{jk} + \omega\bullet\epsilon_{jk} \qquad 0 \leq \omega \leq 1$$

where ω is determined so that the expression

(6) $$\alpha^t_{j+1} - \sum_{k,\ell} \varrho^t_{jk\ell} \sum_m N^t(1;j,k,\ell,m)$$

is minimized. Substituting (5) in (6), we find that this expression is minimized when

$$(7) \quad \omega = \begin{cases} 0 & \text{if } \epsilon_{jk} = \delta_{jk} \text{ for all } k \\ \min\left(1, \dfrac{\alpha_{j+1}^{t} - p_j}{\sum_{k,\ell}(\epsilon_{jk\ell} - \delta_{jk\ell})\sum_{m} N^{t}(1;j,k,\ell,m)}\right) & \text{otherwise.} \end{cases}$$

Hence we define ϱ_{jk}^{t} by equations (5) and (7).

The rationale for modeling promotion behavior this way is to attempt to capture persistent promotion characteristics of the rating as they are reflected in the average historical promotions and at the same time respond to changes in accessions, continuation and endstrength requirements. There are clearly other ways to adjust promotions to meet these requirements, and these alterations could be developed if desired.

We shall now turn to the description of normal rotation. There are six rotation types:

sea to shore
sea to neutral
shore to sea
shore to neutral
neutral to sea
neutral to shore.

It is convient to denote these rotation types by a 2-component vector $\phi = \phi_1, \phi_2$ where

$$(8) \qquad 1 \leq \phi_1, \phi_2 \leq 3 \text{ and } \phi_1 \neq \phi_2$$

(e.g. ϕ = 2,3 represents shore to neutral rotation). The rotation pattern for each paygrade j and rotation type ϕ in period t is defined an $\underline{M}$-component vector $\mu_{j\phi}^{t}$, where the m-th component is the percentage of personnel following rotation type ϕ who are sent to a tour length of m quarters. That is, for each LOS ℓ

$$\mu_{j\phi m}^{t} \cdot N^{t}(2;j, \phi, \ell, 1)$$

personnel are sent to duty-type ϕ_2 for a tour length of m quarters. We have assumed that this percentage is independent of the LOS category ℓ. This allows the user to send individuals to tours of varying length in order to obtain a more uniform personnel distribution between sea, shore and neutral duty. The only theoretical restrictions on these rotation vectors is that all individuals in cells $(j,k,\ell,1)$ must rotate to a new duty type, i.e., for each a is $1 \le k \le 3$

$$\sum_{\substack{\phi \\ \phi_1 = k}} \sum_{m} \mu^{t}_{j\phi m} = 1.$$

The input required to generate the period t+1 inventory from period t inventory is the set of vectors γ^t_{jk}, ρ_{jk}, ϵ_{jk} and $\mu^t_{j\phi}$ for all indices in the ranges defined by (1) and (8). If we define any of these vectors to be zero if one of the indices does not satisfy conditions (1) or (8), then $N^{t+1}(0;j,k,\ell,m)$ is given by

$$(9) \qquad N^{t+1}(0;j,k,\ell,m) = A^t(j,k,\ell,m) + N^t(2;j,k,\ell-1,m+4)$$

$$+ \rho^t_{j-1k} \cdot N^t(2;j-1,k,\ell-1,m+4)$$

$$+ \sum_{\substack{\phi \\ \phi_2 = k}} \sum_{p=1}^{4} \mu^t_{j\phi\, m+p} \cdot [N^t(2;j,\phi_1,\ell-1,p)$$

$$+ \rho^t_{j-1\,\phi_1} \cdot N^t(1;j-1,\phi_1,\ell-1,p)]$$

The process described in equation (9) represents personnel flows subject to normal rotation. However, as remarked earlier, there are ratings in which a significant portion of the inventory does not rotate normally. Factors such as operational holds, humanitarian considerations, and leave taken between tour assignments cause changes in individual PRD's. In order to account for this, early and late rotation behavior has been modeled. The user has the option to consider early and late rotation or not.

Late rotation for each paygrade j is modeled as a "shift" in the period t inventory before projection to period t+1 is begun. Late rotation vectors λ^t_{jk} of $\underline{M}$ components are specified so that the m-th component λ^t_{jkm} is the percentage of the inventory who would normally rotate in period t but are re-assigned to a new PRD of m quarters instead. That is, for m>4, $N^t(0;j,k,\ell,m)$ is replaced by

$$N^t(0;j,k,\ell,m) + \lambda^t_{jkm} \cdot \sum_{n=1}^{4} N^t(0;j,k,\ell,n) \quad ;$$

and then $N^t(0;j,k,\ell,m)$, for m = 1,2,3,4, is replaced by

$$(1 - \sum_n \lambda^t_{jkn}) \cdot N^t(0;j,k,\ell,m)$$

The new values of $N^t(0;j,k,\ell,m)$ obtained by this shift represent the effect of late rotation.

Early rotation for each paygrade; is modeled by a 6-component vector $\sigma^t_{j\phi}$ in which the n-th component $\sigma^t_{j\phi n}$ is the percentage of the inventory $\sum_\ell \sum_{m>4} N^t(0;j,\phi_1,\ell,m)$ that will rotate early to duty type ϕ_2. We assume that the early rotating individuals are distributed equally in cells (j,ϕ_1,ℓ,m) for m = 1,2,3,4. Therefore each of these cells contains

$$N^t_\phi(0;j,\phi_1,\ell,m) = \frac{1}{4}\,\sigma^t_{j\phi} \cdot \sum_\ell \sum_{m>4} N^t(0;j,\phi_1,\ell,m)$$

early rotators who will rotate to duty type ϕ_2. We must then shift the normally rotating inventory by replacing $N^t(0;j,\phi_1,\ell,m)$, for m>4, by $(1-\sigma^t_{j\phi})\ N^t(0;j,\phi_1,\ell,m)$.

We assume that the early rotators $N^t_\phi\,(0;j,\phi_1,\ell,m)$ (m=1,2,3,4) will be assigned to tour lengths determined by the normal rotation vectors $\mu^t_{j\phi}$, but since all of these people are rotating to duty type ϕ_2, we apply to them a "normalized" normal rotation pattern

$$\tilde{\mu}^t_{j\phi} = \left(\frac{1}{\sum_m \mu^t_{j\phi m}}\right)\mu^t_{j\phi}$$

to determine the percentage who are sent to each tour length.

The inventory is decomposed into early rotating components and a shifted portion (excluding early rotators) which is subject to the normal rotation process; let $SN^t(0;j,k,\ell,m)$ denote the number of personnel in cell (j,k,ℓ,m) of this portion of the inventory. Then the transformation equation becomes

(9') $$N^{t+1}(0;j,k,\ell,m) = A^t(j,k,\ell,m) + SN^t(2;j,k,\ell-1,m+4)$$

$$+ \varrho^{t}_{j-1\ k}\dot{}\,SN^{t}(1;j-1,k,\ell-1,m+4)$$

$$+ \sum_{\substack{\phi \\ \phi_2=k}} \sum_{p=1}^{4} \mu^{t}_{j\phi\ m+p}[SN^{t}(2;j,\phi_1,\ell-1,p)$$

$$+ \varrho^{t}_{j-1\phi_1}\dot{}\ SN^{t}(1;j-1,\phi_1,\ell-1,p)]$$

$$+ \sum_{\substack{\phi \\ \phi_2=k}} \sum_{p=1}^{4} \tilde{\mu}^{t}_{j\phi\ m+p}[N^{t}(2;j,\phi_1,\ell-1,p)$$

$$+ \varrho^{t}_{j-1\phi_1}\dot{}\ N^{t}(1;j-1,\phi_1,\ell-1,p)] \ .$$

The last summation vanishes if early rotation is not considered, and (9') reduces to (9) if neither early or late rotation is considered. Equation (9') can be summarized by the following steps:

- (i) shift inventory for late rotation
- (ii) shift for early rotation, form early rotating components
- (iii) determine attrition
- (iv) determine promotion
- (v) rotate
- (vi) add accessions.

In ROTATIONMOD these steps are accomplished by the PROJECT function, which does not use equation (9') directly. For each paygrade the inventory cells are grouped into a 3 x $\underline{L}$ x $\underline{M}$ array; then the computations can be done by simple APL operations on arrays.

ACCURACY OF THE MODEL

The model has been tested on several ratings. The table below shows the percent error between projections and historical results from the enlisted master record (EMR). For each rating the 1977 inventory was projected from the actual 1976 inventory using 1976/1977 historical continuation, accessions, and rotation data with 1977 endstrengths. Then the ratio of the number of individuals in the projection who are in the wrong duty type divided by the paygrade total was computed.

Ratings	Paygrades 1,2,3	4	5	6	7	8	9
AQ	0.0	0.8	0.2	0.9	4.7	4.8	-
MS	0.8	2.1	0.1	0.2	0.4	1.5	0.1
SeaBees	0.4	0.6	1.7	1.3	1.3	2.2	0.0

FIG. A-1: PERCENT ERROR IN ONE YEAR PROJECTIONS

Most of the differences are approximately one percent with the exception of the E-7's and E-8's of the AQ community (there are not E-9's in the AQ rating) two very small groups. However, the absolute differences in the projected sea/shore distribution for and the actual distribution these two paygrades are 10 and 5 respectively.

APPLICATIONS OF THE MODEL

In this section we describe some ways in which the model can be used; most of these have already been implemented in ROTATIONMOD.

Let us fix j, k and two time periods $t_1 < t_2$; further let ϕ, ϕ', be the pair of rotation types such that $\phi'_2 = \phi_{2'} = k$. If Δ represents the total number of personnel who are scheduled to rotate from duty type k in period t_2-1, then any factor which influences Δ also affects the size of duty type k in period t_2. Holding all other variables constant, Δ depends on how many individuals are sent to duty type k in period t_1. That is,

$$\Delta = \Delta_\phi + \Delta_{\phi'} + \text{(other terms)},$$

where $\Delta_\phi = \Delta_\phi(\mu^{t_1}_{j\phi})$ is the number of individuals in paygrade; who rotated from duty type ϕ_1 in period t_1, and at t_2-1 have a PRD $\leq$ 4. Let $\Delta_\phi(m)$ be the value of Δ_ϕ if all these individuals were sent to a tour length of m quarters. Then if

$$\mu^{t_2}_{j\phi} = (r_1 \; , \ldots , \; r_{\underline{M}})$$

the linearity in (9') implies

$$\text{(10)} \qquad \Delta_\phi = \sum_{m=1}^{M} r_m \Delta_\phi(m).$$

The user may solve this equation for values of r_m which will produce a desired value of Δ_ϕ; the only restriction being that $0 \leq r_m \leq 1$. For instance, if a projection with a given rotation pattern yields too many people in duty type k at period t_2, the user could determine values for r_m in (10) which would increase Δ_ϕ. The program COMPTR computes the coefficients $\Delta_\phi(m)$ and $\Delta_{\phi'}(m)$ $(1 \leq m \leq M)$.

The other terms in Δ come from promotions into paygrade j in time periods between t_1 and t_2-1. If these predominate, then adjustments in (10) may have little effect on duty type distributions.

If we let N^t be the vector whose components are $N^t(0;j,k,\ell,m)$, for all j,k,ℓ,m, ordered in some fixed way, and A^t a vector with components $A^t(j,k,\ell,m)$, then equation (9') can be expressed more compactly by

$$(11) \qquad N^{t+1} = \Theta^t(N^t) + A^t,$$

where Θ^t is an operator which has the decomposition

$$\Theta^t = R^t \cdot P^t \cdot C^t$$

and C^t represents attrition, P^t represents promotions and R^t the operation of rotation. Clearly R^t and C^t are linear operators, while P^t is not since it depends on the magnitude of N^t. Let n^t be the sum of the components of N^t and let a^t be the sum of the components of A^t. Then if we define

$$\theta^t = \frac{n^{t+1}-a^t}{n^t}$$

we can write

$$(11') \qquad n^{t+1} = \theta^t \cdot n^t + a^t .$$

Thus θ^t is the percent of the period t total inventory who remain in the Navy throughout period t. If the sequence of accessions $\{a^t\}$ is changed, then (11') will give <u>estimates</u> of the resulting total inventory; these will not be exact because the overall continuation rates θ^t are dependent on inventory size. Suppose that we have constant total accessions a, then (11') gives

$$n^t = n^o \cdot \prod_{j=1}^{t} \theta^i + a(1+\sum_{j=2}^{t} (\prod_{i=j}^{t} \theta^i)) .$$

If we want to determine a so that the inventory at period t is a given size n, then the above equation implies

$$a = \frac{n - n^o \prod_{i=1}^{t} \theta^i}{1 + \sum_{j=1}^{t} \prod_{i=j}^{t} \theta^i} \qquad (12)$$

A new projection based on total accessions a will produce a new total inventory sequence n_1^t; and the process can be repeated with the new values of θ^t determined by n_1^t if $n_1^t - n$ is not sufficiently small. The function COMPTA is based on equation (12) and is intended to be applied iteratively.

As a final application consider the steady-state case

$$N = \Theta N + A. \qquad (13)$$

Suppose that Θ and A are given. Then it is easy to see that (13) has a solution N and that N is unique up to a scalar multiple, for if m > 0,

$$N = \Theta^m N + \Theta^{m-1} A + \ldots + \Theta A + A.$$

But $\Theta^m N = 0$ if m > $\underline{L}$; so in particular

$$N = \left(\sum_{i=0}^{L} \Theta^i\right) A.$$

As a consequence we see that for the steady-state inventory N, ratios between paygrade endstrengths and ratios between duty types are completely determined by Θ and A. Thus the steady-state inventory is very strongly structured; in particular if a specific level of sea manning is desired, then the corresponding size of the shore component is determined by these ratios.

For practical purposes the steady-state inventory can be determined inductively from equation (9'). That is, clearly

$$N(0;j,k,\ell,m) = A(j,k,\ell,m), \text{ for all } j,k,m.$$

Now suppose that all $N(0;j,k,\ell,m)$ have been determined for $\ell < \ell'$, then the quantities $N(0;j,k,\ell',m)$ can be obtained by solving equation (9'). A computer program to do this could be written without much difficulty.

APPENDIX B

PROGRAM LISTING AND FLOW CHARTS

APPENDIX B

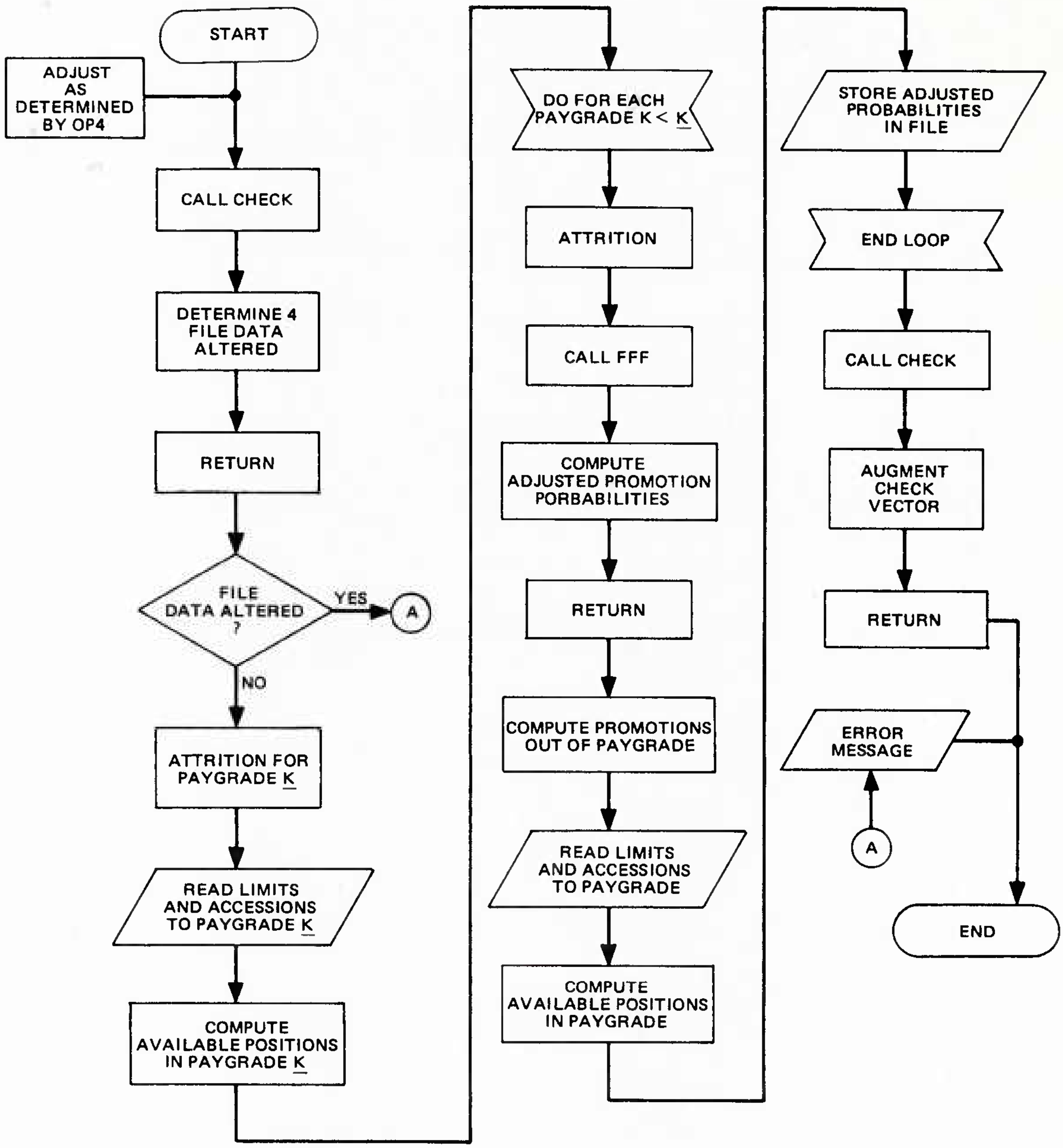
PROGRAM LISTING AND FLOW CHARTS

This section contains a listing of all programs (including calling functions) in ROTATIONMOD. Most of these programs are short and are not as compactly written as they could be. Consequently, they should not be difficult to decipher. Therefore, flow diagrams accompany only those programs which are relatively long or have a fairly complicated logical structure.

User-oriented functions are listed first in alphabetical order. Then the system functions are listed, also alphabetically. When a function consists of several modules stored in the MOD file, the listing begins with the calling function and then each module is listed, the order being determined by the MOD file component in which it is stored.

```
    ∇ ADJPROB T
[1]   ⎕FX■[24]'MOD'
[2]   ADJPROBB T
[3]   ⎕EX'ADJPROBB'
    ∇
```

```
    ∇ ADJPROBB T;K;ADJPROBPROM;AVAILSLOTS;ACCESSIONS;A;
      CH;CONTINUATION;INVENTORY;PGLIM;PROMOTIONS;
      PROMSUM;TT
[1]   TT←((OP4[2]-1)×OP4[1])+(1-OP4[1])×T
[2]   0 CHECK(1+OP1),TT
[3]   →(CH=0)/0
[4]   K←K
[5]   ATTRITION OP1,K,TT
[6]   READFILE OP1,9,K,TT
[7]   READFILE OP1,2,K,TT+1
[8]   AVAILSLOTS←0⌈PGLIM-(+/+/+/INVENTORY)++/+/+/
      ACCESSIONS
[9]   ACCESSIONS←INVENTORY←0
[10] LP:K←K-1
[11]  ATTRITION OP1,K,TT
[12]  FFF
[13]  PROMSUM←+/+/+/INVENTORY×(3,L,M)⍴((⍉(M,L)⍴
      ADJPROBPROM[1;]),[1]⍉(M,L)⍴ADJPROBPROM[2;]),[1]⍉(
      M,L)⍴ADJPROBPROM[3;]
[14]  READFILE OP1,9,K,TT
[15]  READFILE OP1,2,K,TT+1
[16]  AVAILSLOTS←0⌈PGLIM+PROMSUM-(+/+/+/INVENTORY)++/+/
      +/ACCESSIONS
[17]  WRITEFILE OP1,10,K,TT
[18]  ACCESSIONS←INVENTORY←PROMOTIONS←0
[19]  →(K≥2)/LP
[20]  →(OP4[1]=1)/SKIP
[21]  1 CHECK(1+OP1),TT
[22]  →0
[23] SKIP:(OP1,0)FILEALT TT
    ∇
```


START
ADJUST AS DETERMINED BY OP4
CALL CHECK
DETERMINE 4 FILE DATA ALTERED
RETURN
FILE DATA ALTERED ?
YES
A
NO
ATTRITION FOR PAYGRADE K
READ LIMITS AND ACCESSIONS TO PAYGRADE K
COMPUTE AVAILABLE POSITIONS IN PAYGRADE K
DO FOR EACH PAYGRADE K < K
ATTRITION
CALL FFF
COMPUTE ADJUSTED PROMOTION PORBABILITIES
RETURN
COMPUTE PROMOTIONS OUT OF PAYGRADE
READ LIMITS AND ACCESSIONS TO PAYGRADE
COMPUTE AVAILABLE POSITIONS IN PAYGRADE
STORE ADJUSTED PROBABILITIES IN FILE
END LOOP
CALL CHECK
AUGMENT CHECK VECTOR
RETURN
ERROR MESSAGE
A
END

```
    ∇ CHANGE X;A;DT;BR;Z
[1]   A←15 26⍴'BILLETS                   PAYGRADE
      LIMITS          PROMOTION PROBABILITIES
      ELIGIBLE PROBABILITIES    CONTINUATION
         EARLY ROTATION           NORMAL ROTATION
            LATE ROTATION            ACCESSIONS
               ADJUSTED PROBABILITIES    INVENTORY
                  SUMMARY                   PROMOTIONS
                     SURVIVING INVENTORY
      PREPARED INVENTORY          '
[2]   DT←1
[3]  LOOP:→(26=+/(X,(26-⍴X)⍴' ')=A[DT;])/OUT
[4]   DT←DT+1
[5]   →(DT≤15)/LOOP
[6]   →(DT≥16)/ERR
[7]  OUT:'SPECIFY DATA COMPARTMENT(0 OR 1)'
[8]   Z←⎕
[9]   ⎕FX⊞[39+DT]'MOD'
[10]  CHANGEE Z
[11]  ⎕EX'CHANGEE'
[12]  →0
[13] ERR:'INCORRECT DATA TYPE'
    ∇
```

```
    ∇ CHANGEE X;A;BR;I;J;PGLIM;TM
[1]   HEADER 5
[2]   →(BR=1)/END
[3]   'ENTER A VECTOR ALTERNATING'
[4]   'PAYGRADES AND NEW PAYGRADE LIMITS'
[5]   A←⎕
[6]   J←1
[7]  LOOP1:I←1
[8]  LOOP2:READFILE X,2,A[(2×I)-1],TM[J]
[9]   PGLIM←A[2×I]
[10]  WRITEFILE X,2,A[(2×I)-1],TM[J]
[11]  →(((⍴A)÷2)≥I←I+1)/LOOP2
[12]  (X,0)FILEALT TM[J]
[13]  →(TM[J]≤0)/CONT
[14]  (X,0)FILEALT TM[J]-1
[15] CONT:J←J+1
[16]  →(J≤⍴TM)/LOOP1
[17] END:→0
    ∇
```

```
     ∇ CHANGEE X;A;B;DU;I;CONTINUATION;V;Z
[1]  LOOP1:'ENTER AS A NUMERIC VECTOR: PAYGRADE,TIME
      PERIOD'
[2]   Z←⎕
[3]  LOOP2:HEADER 2
[4]   →(BR=1)/END
[5]   READFILE X,5,Z[1],Z[2]
[6]   'ENTER CHANGES IN CONTINUATION AS A NUMERIC
      VECTOR WHOSE COMPONENTS'
[7]   'ARE ALTERNATLY LOS AND NEW LOS VALUE'
[8]   V←⎕
[9]   I←1
[10] LOOP3:CONTINUATION[V[(2×I)-1];DU]←V[2×I]
[11]  →(((ρV)÷2)≥I←I+1)/LOOP3
[12]  WRITEFILE X,5,Z[1],Z[2]
[13]  (X,1)FILEALT Z[2]
[14]  'DO YOU WANT TO CHANGE CONTINUATION IN ANOTHER'
[15]  ⍞←'DUTY TYPE? '
[16]  →(3≠ρB←11↓⍞)/CONT
[17]  →(3=+/B='YES')/LOOP2
[18] CONT:'DO YOU WANT TO CHANGE CONTINUATION IN
      ANOTHER'
[19]  ⍞←'PAYGRADE OR TIME PERIOD? '
[20]  →(3≠ρB←25↓⍞)/0
[21]  →(3=+/B='YES')/LOOP1
[22] END:→0
     ∇
```

```
    ∇ CHANGEE X;A;B;EROT;I;V;Z
[1]    A←6 16⍴'SEA TO SHORE    SEA TO NEUTRAL  SHORE TO
       SEA     SHORE TO NEUTRALNEUTRAL TO SEA  NEUTRAL
       TO SHORE'
[2]   LOOP1:'ENTER AS A NUMERIC VECTOR: PAYGRADE,TIME
       PERIOD'
[3]    Z←⎕
[4]    READFILE X,6,Z[1],Z[2]
[5]    I←0
[6]    'ENTER CHANGES IN EARLY ROTATION,IF NO CHANGE
       TYPE →C'
[7]   LOOP:⍞←A[I←I+1;],': '
[8]   ERR:V←18↓⍞
[9]    →(2=+/V∊'→C')/STEP
[10]   →((⍴,⍎V)=1)/CONT
[11]   'INCORRECT ENTRY,TRY AGAIN'
[12]   →ERR
[13]  CONT:EROT[I]←⍎V
[14]  STEP:→(6>I)/LOOP
[15]   WRITEFILE X,6,Z[1],Z[2]
[16]   (X,1)FILEALT Z[2]
[17]   'DO YOU WANT TO CHANGE NORMAL ROTATION IN
       ANOTHER'
[18]   ⍞←'PAYGRADE OR TIME PERIOD? '
[19]   →(3≠⍴B←25↓⍞)/0
[20]   →(3=+/B='YES')/LOOP1
[21]  END:→0
[22]   →(6>I)/LOOP
    ∇
```

```
    ∇ CHANGEE X;B;I;V;RT;NROT;Z
[1]  LOOP1:'ENTER AS A NUMERIC VECTOR: PAYGRADE,TIME
      PERIOD'
[2]   Z←⎕
[3]   HEADER 7
[4]   →(BR=1)/END
[5]   READFILE X,7,Z[1],Z[2]
[6]   'ENTER CHANGES IN NORMAL ROTATION AS A NUMERIC
      VECTOR WHOSE COMPONENTS'
[7]   'ARE ALTERNATLY TOUR LENGTH AND NEW TOUR LENGTH
      VALUE'
[8]   V←⎕
[9]   I←1
[10] LOOP2:NROT[RT;V[(2×I)-1]]←V[2×I]
[11]  →(((ρV)÷2)≥I←I+1)/LOOP2
[12]  WRITEFILE X,7,Z[1],Z[2]
[13]  (X,1)FILEALT Z[2]
[14]  'DO YOU WANT TO CHANGE NORMAL ROTATION IN
      ANOTHER'
[15]  ⍞←'PAYGRADE OR TIME PERIOD? '
[16]  →(3≠ρB←25↓⍞)/0
[17]  →(3=+/B='YES')/LOOP1
[18] END:→0
    ∇
```

```
    ∇ CHANGEE X;A;B;DU;I;LROT;V;Z
   LOOP1:'ENTER AS A NUMERIC VECTOR: PAYGRADE,TIME
     PERIOD'
     Z←⎕
   LOOP2:HEADER 2
     →(BR=1)/END
     READFILE X,8,Z[1],Z[2]
     'ENTER CHANGES IN LATE ROTATION AS A NUMERIC
     VECTOR WHOSE COMPONENTS'
     'ARE ALTERNATLY TOUR LENGTH AND NEW TOUR LENGTH
     VALUE'
     V←⎕
     I←1
   LOOP3:LROT[DU;V[(2×I)-1]]←V[2×I]
     →(((ρV)÷2)≥I←I+1)/LOOP3
     WRITEFILE X,8,Z[1],Z[2]
     (X,1)FILEALT Z[2]
     'DO YOU WANT TO CHANGE LATE ROTATION IN ANOTHER'
     ⍞←'DUTY TYPE? '
     →(3≠ρB←11↓⍞)/CONT
     →(3=+/B='YES')/LOOP2
   CONT:'DO YOU WANT TO CHANGE LATE ROTATION IN
     ANOTHER'
     ⍞←'PAYGRADE OR TIME PERIOD? '
     →(3≠ρB←25↓⍞)/0
     →(3=+/B='YES')/LOOP1
   END:→0
    ∇
```

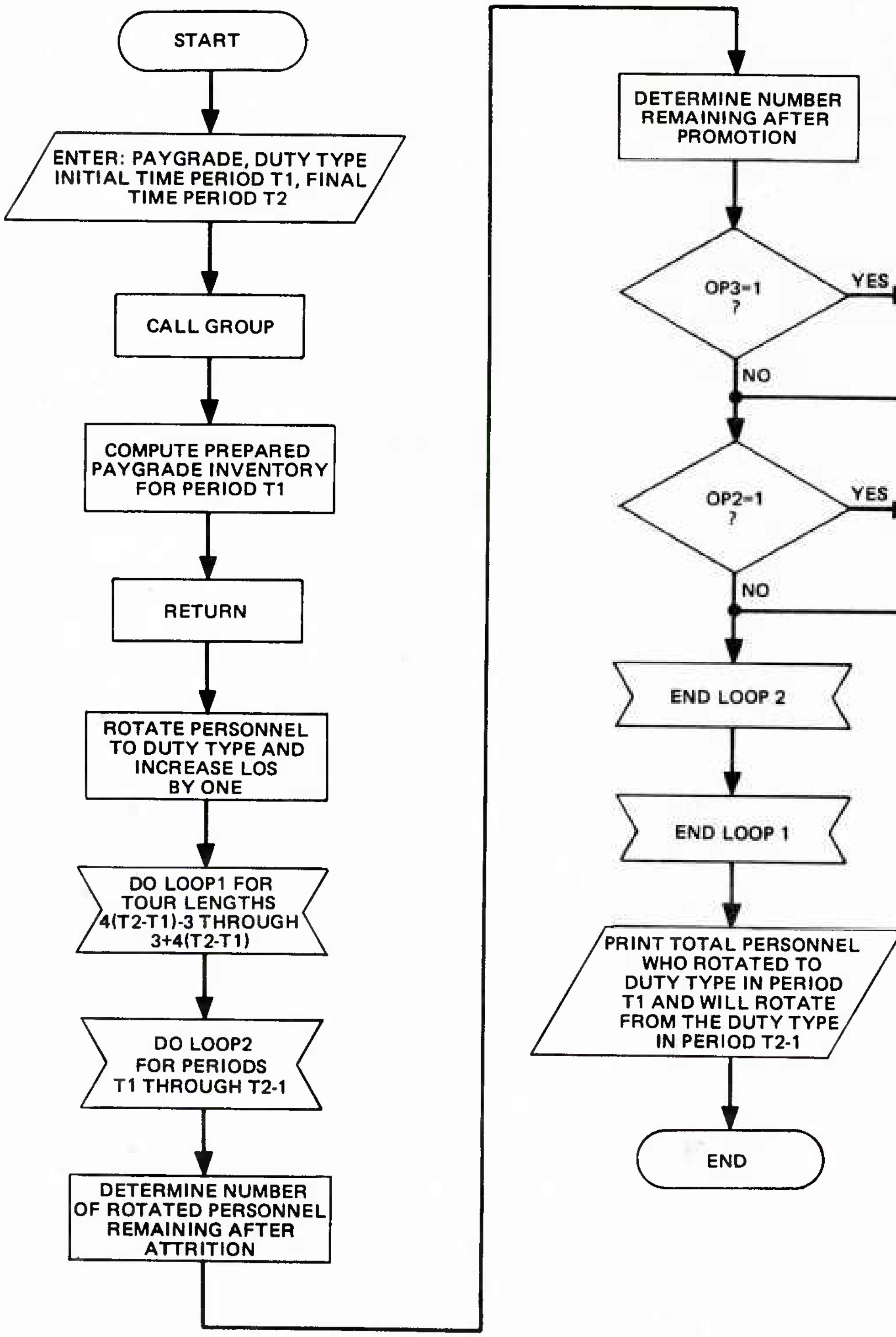
```
     ∇ CHANGEE X;A;ACCESSIONS;DU;I;J;PG;TM;B;C;D;E
[1]    HEADER 4
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    'ACCESSION CHANGES CAN BE MADE BY SCALING THE
       CURRENT'
[6]    'ACCESSIONS ARRAY,OR BY REPLACING A DUTY TYPE
       MATRIX WITH A NEW ONE'
[7]    'ENTER CHANGE IN ACCESSIONS(POSITIVE OR NEGATIVE)
        OR ';L;'x';M;' ACCESSIONS MATRIX'
[8]    A←⎕
[9]    J←1
[10]  LOOP1:I←1
[11]  LOOP2:READFILE X,9,PG[I],TM[J]
[12]   →((⍴⍴A)=2)/MATRIX
[13]   ACCESSIONS+←(3,L,M)⍴B\D\E×A÷+/E←(D←C>0)/C←(B←,
       ACCESSIONS≠0)/,ACCESSIONS
[14]   →CONT
[15]  MATRIX:HEADER 2
[16]   →(BR=1)/END
[17]   ACCESSIONS[DU;;]←A
[18]  CONT:WRITEFILE X,9,PG[I],TM[J]
[19]   ACCESSIONS←0
[20]   I←I+1
[21]   →(I≤⍴PG)/LOOP2
[22]   (X,0)FILEALT TM[J]
[23]   (X,1)FILEALT TM[J]
[24]   J←J+1
[25]   →(J≤⍴TM)/LOOP1
[26]  END:→0
     ∇
```

```
      ∇COMPTA[⎕]∇
     ∇ COMPTA
[1]    ⎕FX⍞[51]'MOD'
[2]    COMPTAA
[3]    ⎕EX'COMPTAA'
     ∇
```

```
    ∇ COMPTAA;A;ACCESSIONS;I;INVENTORY;OP5;SUMMARY;U;X;
      CH
[1]   'ENTER DESIRED INVENTORY SIZE'
[2]   X←⎕
[3]   'ENTER TIME PERIOD AT WHICH DESIRED INVENTORY IS
      TO BE ATTAINED'
[4]   X←X,⎕
[5]   →((X[2]+1)>⍴CH←⍞[(1+OP1)×2+⌶]'FILE3')/EXIT1
[6]   →(0<+/((X[2]+1)⍴1)=(X[2]+1)↑CH)/EXIT2
[7]   OP5←1,⍷
[8]   U←⍳0
[9]   I←0
[10] LOOP1:OP6 GROUP OP1,12,1,I
[11]  →(I>0)/LAB
[12]  INVENTORY←SUMMARY[2]
[13]  A←SUMMARY[5]
[14] LAB:U←U,(SUMMARY[7]-A)÷SUMMARY[2]
[15]  I←I+1
[16]  →(I≤X[2]-1)/LOOP1
[17]  ACCESSIONS←(X[1]-INVENTORY××/U)÷1++/×\⌽1↓U
[18]  'ESTIMATED ASSESSIONS PER PERIOD FOR PERIODS 0
      THROUGH ';X[2]-1;' :'
[19]  ' '
[20]  ACCESSIONS
[21]  →0
[22] EXIT1:'IN ORDER TO USE COMPTA THE INVENTORY MUST'
[23]  'BE PROJECTED TO AT LEAST PERIOD ';X[2]
[24]  →0
[25] EXIT2:'INPUT DATA AFFECTING THIS COMPUTATION HAS
      BEEN'
[26]  'ALTERED SINCE LAST PROJECTION'
    ∇
```

```
    ∇ COMPTR
      ⎕FX⌹[50]'MOD'
      COMPTRR
      ⎕EX'COMPTRR'
    ∇


    ∇ COMPTRR;A;B;BR;C;D;INVENTORY;T;ADJPROBPROM;
      CONTINUATION;E;EROT;I;J;LROT;F;U;K;DU;BB;G;NROT
      'FOR A PAYGRADE GROUP (DEFINED BY OP5) AND DUTY
      TYPE,'
      'COMPTR DESCRIBES THE EFFECT OF CHANGES IN
      NORMAL ROTATION'
      'AT A PERIOD T1 ON THE TOTAL PERSONNEL IN THE
      DUTY TYPE AT A'
      'SUBSEQUENT PERIOD T2>1+T1'
      'ENTER PAYGRADE GROUP'
      C←⎕
      HEADER 2
      D←((3⍴DU)≠⍳3)/⍳3
      'ENTER PERIOD T1'
      T←⎕
      'ENTER PERIOD T2'
      C←C,⎕-1
      BB←B←(3+⍳M-2),[1](2,M-2)⍴0
      U←OP5
      K←U[(2×C[1])-1]
    LOOP:OP5←K,K
      (((62⍴1 0)\⍳L)+(62⍴0 1)\⍳L)GROUP OP1,15,1,T
      E←INVENTORY[;;1,2,3,4]
      INVENTORY←0
      I←(4×C[2]-T)-3×1<C[2]-T
    LOOP1:F←(2,L,M)⍴0
      F[1;;(I-3),(I-2),(I-1),I]←(¯1⌽[2]E)[D[1];;]
      F[2;;(I-3),(I-2),(I-1),I]←(¯1⌽[2]E)[D[2];;]
      J←1
    LOOP2:READFILE OP1,10,K,T+J
      F←F×1-(2,L,M)⍴(⍉(M,L)⍴ADJPROBPROM[DU;]),[1]⍉(M,L)
      ⍴ADJPROBPROM[DU;]
      READFILE OP1,5,K,T+J
      F←F×(2,L,M)⍴(⍉(M,L)⍴CONTINUATION[;DU]),[1]⍉(M,L)⍴
      CONTINUATION[;DU]
      →(OP3=0)/LATE
      READFILE OP1,6,K,T+J
      F[1;;4+⍳M-4]←F[1;;4+⍳M-4]×1-EROT[DU]+EROT[DU]
```

```
[32]  F[2;;4+⍳M-4]←F[2;;4+⍳M-4]×1-EROT[DU]+EROT[DU]
[33] LATE:→(OP2=0)/NORM
[34]  READFILE OP1,8,K,T+J
[35]  G←F[;;1,2,3,4]
[36]  F[1;;1,2,3,4]←F[1;;1,2,3,4]×1-+/LROT[DU;]
[37]  F[1;;]←F[1;;]+((L,M)⍴LROT[DU;])×⍉(M,L)⍴+/G[1;;]
[38]  F[2;;1,2,3,4]←F[2;;1,2,3,4]×1-+/LROT[DU;]
[39]  F[2;;]←F[2;;]+((L,M)⍴LROT[DU;])×⍉(M,L)⍴+/G[2;;]
[40]  G←0
[41] NORM:→(C[2]<T+J←J+1)/OUT
[42]  F←4⌽¯1⌽[2]F
[43]  F[;;(M-3),(M-2),(M-1),M]←0
[44]  →LOOP2
[45] OUT:B[2,3;I-3]←+/+/F[;;1,2,3,4]
[46]  →((3+4×C[2]-T)≥I←I+1)/LOOP1
[47]  BB[2,3;⍳M-3]←BB[2,3;⍳M-3]+B[2,3;⍳M-3]
[48]  READFILE OP1,7,K,T
[49]  G←B[2,3;⍳M-3]+.×⍉0 3↓NROT[(3 2⍴3 5 1 6 2 4)[DU;];
      ]
[50]  BB[2;M-2]←BB[2;M-2]+G[1;1]
[51]  BB[3;M-2]←BB[3;M-2]+G[2;2]
[52]  →(U[2×C[1]]≥K←K+1)/LOOP
[53]  OP5←U
[54]  4 1⍴' '
[55]  'PAYGRADE GROUP ';C[1];':'
[56]  'OP2 = ';OP2
[57]  'OP3 = ';OP3
[58]  'OP5 = ';OP5
[59]  ' '
[60]  '--------------------------------------------------------------------------------------------------------
      ---------------------------------------------'
[61]  'TOUR LENGTH          ';(3,0)⍕B[1;⍳M-3]
[62]  ' '
[63]  A[D[1];];' TO ';A[DU;];'  ';(3,0)⍕BB[2;⍳M-3];'   '
      ;(3,0)⍕BB[2;M-2]
[64]  A[D[2];];' TO ';A[DU;];'  ';(3,0)⍕BB[3;⍳M-3];'   '
      ;(3,0)⍕BB[3;M-2]
[65]  ' '
[66]  'FOR EACH INDICATED ROTATION TYPE,THE CHANGE IN
      TOTAL PERSONNEL AT ';(A[DU;]≠7⍴' ')/A[DU;];' IN'
[67]  'PERIOD ';C[2]+1;' DUE TO AN ALTERED ROTATION
      TYPE VECTOR R IN PERIOD ';T;' IS'
[68]  '               E-+/R×A               '
[69]  'WHERE A IS THE VECTOR CONSISTING OF THE FIRST
      17 ENTRIES AND E IS THE'
[70]  'THE LAST ENTRY IN THE ROW CORRESPONDING TO THE
      ROTATION TYPE'
    ∇
```


START
ENTER: PAYGRADE, DUTY TYPE INITIAL TIME PERIOD T1, FINAL TIME PERIOD T2
CALL GROUP
COMPUTE PREPARED PAYGRADE INVENTORY FOR PERIOD T1
RETURN
ROTATE PERSONNEL TO DUTY TYPE AND INCREASE LOS BY ONE
DO LOOP1 FOR TOUR LENGTHS 4(T2-T1)-3 THROUGH 3+4(T2-T1)
DO LOOP2 FOR PERIODS T1 THROUGH T2-1
DETERMINE NUMBER OF ROTATED PERSONNEL REMAINING AFTER ATTRITION
DETERMINE NUMBER REMAINING AFTER PROMOTION
OP3=1 ?
YES
ELIMINATE EARLY ROTATORS
NO
OP2=1 ?
YES
READJUST TOUR LENGTHS FOR LATE ROTATION
NO
END LOOP 2
END LOOP 1
PRINT TOTAL PERSONNEL WHO ROTATED TO DUTY TYPE IN PERIOD T1 AND WILL ROTATE FROM THE DUTY TYPE IN PERIOD T2-1
END

```
    ∇ FILL;BR
[1]   ⎕FX⌹[8]'MOD'
[2]   FIL
[3]   ⎕EX'FIL'
    ∇
```

```
    ∇ FIL;A;DT;I;K;J;L;M;OP
[1]   'SPECIFY DATA COMPARTMENT(0 OR 1)'
[2]   I←(8+4×I̲)×OP←⎕
[3]   L←OP+J←2×(I̲+1)×K̲×OP
[4]   DT←1
[5]  LOOP:→(DT=⍳12)/L1,L2,L3,L4,L5,L6,L7,L8,L9,L10,L11,
      L12
[6]  L1:((K̲,(I̲+1),3)⍴0)⌹[1+I]'FILE1'
[7]   →END
[8]  L2:(((I̲+1),K̲)⍴0)⌹[2+I]'FILE1'
[9]   →END
[10] L3:((3,L̲,K̲)⍴0)⌹[3+I]'FILE1'
[11]  →END
[12] L4:((3,L̲,K̲)⍴0)⌹[4+I]'FILE1'
[13]  →END
[14] L5:K←1
[15] LP1:((I̲,L̲,K̲)⍴0)⌹[4+K+I]'FILE1'
[16]  K←K+1
[17]  →(K≤3)/LP1
[18]  →END
[19] L7:K←1
[20] LP2:0⌹[8+K+I]'FILE1'
[21]  K←K+1
[22]  →(K≤2×I̲)/LP2
[23]  →END
[24] L9:K←1
[25] LP3:0⌹[K+J]'FILE2'
[26]  K←K+1
[27]  →(K≤2×I̲×K̲)/LP3
[28]  →END
```

```
[29] L11:K←1
[30] LP4:0⎕[1+L+K]'FILE4'
[31]  K←K+1
[32]  →(K≤2×(I̲+1)×K̲)/LP4
[33]  →END
[34] L12:((I̲,7,K̲)⍴0)⎕[L+1]'FILE4'
[35]  →END
[36] L8:K←1
[37] LP5:0⎕[8+K+2×I̲+I]'FILE1'
[38]  K←K+1
[39]  →(K≤2×I̲)/LP5
[40]  →END
[41] L6:((I̲,6,K̲)⍴0)⎕[8+I]'FILE1'
[42]  →END
[43] L10:K←1
[44] LP6:((3,L̲,K̲)⍴0)⎕[K+(I̲+2)×OP]'FILE3'
[45]  K←K+1
[46]  →(K≤I̲)/LP6
[47]  (⍳0)⎕[1+I̲+(2+I̲)×OP]'FILE3'
[48]  (,0)⎕[2+I̲+(2+I̲)×OP]'FILE3'
[49] END:→(12≥DT←DT+1)/LOOP
    ∇
```

```
    ∇ PRINT X;A;DT;BR;Z
[1]   Z←OP1
[2]   A←15 26⍴'BILLETS                   PAYGRADE
      LIMITS           PROMOTION PROBABILITIES
      ELIGIBLE PROBABILITIES    CONTINUATION
         EARLY ROTATION              NORMAL ROTATION
            LATE ROTATION                ACCESSIONS
               PROMOTIONS                   INVENTORY
                  SUMMARY                      ADJUSTED
      PROBABILITIES    SURVIVING INVENTORY
      PREPARED INVENTORY        '
[3]   DT←1
[4]  LOOP:→(26=+/(X,(26-⍴X)⍴' ')=A[DT;])/OUT
[5]   DT←DT+1
[6]   →(DT≤15)/LOOP
[7]   →(DT≥16)/ERR
[8]  OUT:'SPECIFY DATA COMPARTMENT(0 OR 1)'
[9]   OP1←⎕
[10]  ⎕FX⍎[8+DT]'MOD'
[11]  PRINTT
[12]  ⎕EX'PRINTT'
[13]  →EXIT
[14] ERR:'INCORRECT DATA TYPE'
[15] EXIT:OP1←Z
    ∇


    ∇ PRINTT;B;BILTS;I;J;PG;TM
[1]   HEADER 4
[2]   →(BR=1)/END
[3]   HEADER 5
[4]   →(BR=1)/END
[5]   I←1
[6]  LP1:B←((⍴TM),3)⍴0
[7]   J←1
[8]  LP2:((((2×L)⍴1 0)\⍳L)+((2×L)⍴0 1)\⍳L)GROUP OP1,1,
      PG[I],TM[J]
[9]   →(I>(⍴OP5)÷2)/0
[10]  B[J;]←BILTS
[11]  J←J+1
[12]  →(J≤⍴TM)/LP2
[13]  'BILLET REQUIREMENTS FOR PAYGRADE GROUP = ',2 0⍕
      PG[I]
[14]  '(';'OP5=';OP5;')'
[15]  (5,0)PRIN B
[16]  I←I+1
[17]  →(I≤⍴PG)/LP1
[18] END:→0
    ∇
```

```
    ∇ PRINTT;B;I;J;PGLIM;PG;TM
[1]    HEADER 4
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    B←((⍴TM),⍴PG)⍴0
[6]    I←1
[7]   LP1:J←1
[8]   LP2:((((2×L)⍴1 0)\⍳L)+((2×L)⍴0 1)\⍳L)GROUP OP1,2,
       PG[I],TM[J]
[9]    →(I>(⍴OP5)÷2)/0
[10]   B[J;I]←PGLIM
[11]   J←J+1
[12]   →(J≤⍴TM)/LP2
[13]   I←I+1
[14]   →(I≤⍴PG)/LP1
[15]   'PAYGRADE GROUP LIMITS'
[16]   '(';'OP5=';OP5;')'
[17]   (1,0)PRIN B
[18]  END:→0
    ∇
```

```
    ∇ PRINTT;A;B;DU;I;PROBPROM;PG
[1]    HEADER 3
[2]    →(BR=1)/END
[3]   BEGIN:HEADER 2
[4]    →((BR=2)∨BR=1)/END
[5]    B←(L,⍴PG)⍴0
[6]    I←1
[7]   LP:READFILE OP1,3,I,0
[8]    B[;I]←PROBPROM[DU;]
[9]    I←I+1
[10]   →(I≤⍴PG)/LP
[11]   'PROMOTION PROBABILITIES FOR DUTY-TYPE:',A[DU;]
[12]   (2,0)PRIN B
[13]   ⍞←'DO YOU WANT TO PRINT ANOTHER DUTY TYPE? '
[14]   →(3≠⍴B←40↓⍞)/END
[15]   →(3=+/B='YES')/BEGIN
[16]  END:→0
    ∇
```

```
    ∇ PRINTT;A;B;DU;I;ELIG;PG
      HEADER 3
      →(BR=1)/END
     BEGIN:HEADER 2
      →((BR=2)∨BR=1)/END
      B←(L,⍴PG)⍴0
      I←1
     LP:READFILE OP1,4,PG[I],0
      B[;I]←ELIG[DU;]
      I←I+1
      →(I≤⍴PG)/LP
      'ELIGIBLE PROBABILITIES FOR DUTY-TYPE:',A[DU;]
      (2,0)PRIN B
      ⍞←'DO YOU WANT TO PRINT ANOTHER DUTY TYPE? '
      →(3≠⍴B←40↓⍞)/END
      →(3=+/B='YES')/BEGIN
     END:→0
    ∇

    ∇ PRINTT;A;B;CONTINUATION;COUNT;DU;I;J;K;PG;TM
      HEADER 3
      →(BR=1)/END
      HEADER 5
      →(BR=1)/END
      J←1
      K←COUNT←0
     DUTY:HEADER 2
      →((BR=2)∨BR=1)/END
     LP1:B←(L,⍴PG)⍴0
      I←1
     LP2:READFILE OP1,5,PG[I],TM[J]
      B[;I]←CONTINUATION[;DU]
      I←I+1
      →(I≤⍴PG)/LP2
      'CONTINUATION RATES FOR PERIOD = ',2 0⍕TM[J]
      'DUTY-TYPE:',A[DU;]
      (2,0)PRIN B
      COUNT←COUNT+1
      K←K+DU×COUNT=1
      'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
      PROCCEDING'
      ⍞←'TO THE NEXT TIME PERIOD? '
      →(3≠⍴B←25↓⍞)/CONT
      →(3=+/B='YES')/DUTY
     CONT:DU←K
      J←J+1
      →(J≤⍴TM)/LP1
     END:→0
    ∇
```

```
      ∇ PRINTT;B;EROT;I;J;PG;TM
[1]     HEADER 3
[2]     →(BR=1)/END
[3]     HEADER 5
[4]     →(BR=1)/END
[5]     J←1
[6]    LP1:B←((⍴PG),6)⍴0
[7]     I←1
[8]    LP2:READFILE OP1,6,PG[I],TM[J]
[9]     B[I;]←EROT
[10]    I←I+1
[11]    →(I≤⍴PG)/LP2
[12]    'EARLY ROTATION IN PERIOD = ',2 0⍕TM[J]
[13]    (4,2)PRIN B
[14]    J←J+1
[15]    →(J≤⍴TM)/LP1
[16]   END:→0
      ∇
```

```
      ∇ PRINTT;I;J;NROT;PG;TM
[1]     HEADER 3
[2]     →(BR=1)/END
[3]     HEADER 5
[4]     →(BR=1)/END
[5]     J←1
[6]    LP1:I←1
[7]    LP2:READFILE OP1,7,PG[I],TM[J]
[8]     'NORMAL ROTATION FOR PAYGRADE PG = ',(2 0⍕PG[I]),
        ' IN PERIOD TM = ',2 0⍕TM[J]
[9]     (4,0)PRIN⍉NROT
[10]    I←I+1
[11]    →(I≤⍴PG)/LP2
[12]    J←J+1
[13]    →(J≤⍴TM)/LP1
[14]   END:→0
      ∇
```

```
    ∇ PRINTT;I;J;LROT;PG;TM
[1]    HEADER 3
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    J←1
[6]   LP1:I←1
[7]   LP2:READFILE OP1,8,PG[I],TM[J]
[8]    'LATE ROTATION FOR PAYGRADE PG = ',(2 0⍕PG[I]),'
       IN PERIOD TM = ',2 0⍕TM[J]
[9]    (4,1)PRIN⍉LROT
[10]   I←I+1
[11]   →(I≤⍴PG)/LP2
[12]   J←J+1
[13]   →(J≤⍴TM)/LP1
[14]  END:→0
    ∇



    ∇ PRINTT;A;ACCESSIONS;B;C;COUNT;DU;H;I;J;K;PG;TM
[1]    HEADER 4
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    HEADER 6
[6]    →(BR=1)/END
[7]    →(H=1 0)/Q1,Q2
[8]   Q1:HEADER 2
[9]    →((BR=2)∨BR=1)/END
[10]  Q2:I←1
[11]  LP1:B←(3,(⍴TM),3)⍴0
[12]   J←1
[13]  LP2:OP6 GROUP OP1,9,PG[I],TM[J]
[14]   →(H=0)/Q3
[15]   K←COUNT←0
[16]   'ACCESSIONS INTO PAYGRADE GROUP = ',2 0⍕PG[I]
[17]   'IN PERIOD = ',2 0⍕TM[J]
[18]   '(';'OP5=';OP5;')'
[19]   '(';'OP6=';OP6;')'
[20]  DUTY:(3,0)PRIN ACCESSIONS[DU;;]
[21]   COUNT←COUNT+1
[22]   K←K+DU×COUNT=1
[23]   'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
       PROCEEDING'
```

```
[24]  ⍞←'TO THE NEXT PAYGRADE/TIME PERIOD? '
[25]  →(3≠ρB←34↓⍞)/CONT
[26]  →(3≠+/B='YES')/CONT
[27]  HEADER 2
[28]  →((BR=2)∨BR=1)/END
[29]  →DUTY
[30] CONT:ACCESSIONS←0
[31]  DU←K
[32]  J←J+1
[33]  →(J≤ρTM)/LP2
[34]  I←I+1
[35]  →(I≤ρPG)/LP1
[36]  →0
[37] Q3:B[;J;1]←+/+/ACCESSIONS[;;1,2,3,4]
[38]  B[;J;2]←(+/+/ACCESSIONS)-+/+/ACCESSIONS[;;1,2,3,
      4]
[39]  B[;J;3]←+/+/ACCESSIONS
[40]  ACCESSIONS←0
[41]  J←J+1
[42]  →(J≤ρTM)/LP2
[43]  'TOTAL ACCESSIONS INTO PAYGRADE GROUP = ',2 0⍕PG[
      I]
[44]  '(';'OP5=';OP5;')'
[45]  (5,1)PRIN B
[46]  B←0
[47]  I←I+1
[48]  →(I≤ρPG)/LP1
[49] END:→0
    ∇
```

```
∇ PRINTT;A;PROMOTIONS;B;C;COUNT;DU;H;I;J;K;PG;TM
   HEADER 4
   →(BR=1)/END
   HEADER 5
   →(BR=1)/END
   HEADER 6
   →(BR=1)/END
   →(H=1 0)/Q1,Q2
  Q1:HEADER 2
   →((BR=2)∨BR=1)/END
  Q2:I←1
  LP1:B←(3,(⍴TM),3)⍴0
   J←1
  LP2:OP6 GROUP OP1,10,PG[I],TM[J]
   →(H=0)/Q3
   K←COUNT←0
   'PROMOTIONS INTO PAYGRADE GROUP = ',2 0⍕PG[I]
   'IN PERIOD = ',2 0⍕TM[J]
   '(';'OP5=';OP5;')'
   '(';'OP6=';OP6;')'
  DUTY:(3,0)PRIN PROMOTIONS[DU;;]
   COUNT←COUNT+1
   K←K+DU×COUNT=1
   'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
   PROCEEDING'
   ⍞←'TO THE NEXT PAYGRADE/TIME PERIOD? '
   →(3≠⍴B←34↓⍞)/CONT
   →(3≠+/B='YES')/CONT
   HEADER 2
   →((BR=2)∨BR=1)/END
   →DUTY
  CONT:PROMOTIONS←0
   DU←K
   J←J+1
   →(J≤⍴TM)/LP2
   I←I+1
   →(I≤⍴PG)/LP1
   →0
  Q3:B[;J;1]←+/+/PROMOTIONS[;;1,2,3,4]
   B[;J;2]←(+/+/PROMOTIONS)-+/+/PROMOTIONS[;;1,2,3,
   4]
   B[;J;3]←+/+/PROMOTIONS
   PROMOTIONS←0
   J←J+1
   →(J≤⍴TM)/LP2
   'TOTAL PROMOTIONS INTO PAYGRADE GROUP = ',2 0⍕PG[
   I]
   '(';'OP5=';OP5;')'
   (5,1)PRIN B
   B←0
   I←I+1
   →(I≤⍴PG)/LP1
  END:→0
∇
```

```
    ∇ PRINTT;A;INVENTORY;B;C;COUNT;DU;H;I;J;K;PG;TM
[1]   HEADER 4
[2]   →(BR=1)/END
[3]   HEADER 5
[4]   →(BR=1)/END
[5]   HEADER 6
[6]   →(BR=1)/END
[7]   →(H=1 0)/Q1,Q2
[8]  Q1:HEADER 2
[9]   →((BR=2)∨BR=1)/END
[10] Q2:I←1
[11] LP1:B←(3,(ρTM),3)ρ0
[12]  J←1
[13] LP2:OP6 GROUP OP1,11,PG[I],TM[J]
[14]  →(H=0)/Q3
[15]  K←COUNT←0
[16]  'INVENTORY FOR PAYGRADE GROUP = ',2 0⍕PG[I]
[17]  'IN PERIOD = ',2 0⍕TM[J]
[18]  '(';'OP5=';OP5;')'
[19]  '(';'OP6=';OP6;')'
[20] DUTY:(3,0)PRIN INVENTORY[DU;;]
[21]  COUNT←COUNT+1
[22]  K←K+DU×COUNT=1
[23]  'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
      PROCEEDING'
[24]  ⍞←'TO THE NEXT PAYGRADE/TIME PERIOD? '
[25]  →(3≠ρB←34↓⍞)/CONT
[26]  →(3≠+/B='YES')/CONT
[27]  HEADER 2
[28]  →((BR=2)∨BR=1)/END
[29]  →DUTY
[30] CONT:INVENTORY←0
[31]  DU←K
[32]  J←J+1
[33]  →(J≤ρTM)/LP2
[34]  I←I+1
[35]  →(I≤ρPG)/LP1
[36]  →0
[37] Q3:B[;J;1]←+/+/INVENTORY[;;1,2,3,4]
[38]  B[;J;2]←(+/+/INVENTORY)-+/+/INVENTORY[;;1,2,3,4]
[39]  B[;J;3]←+/+/INVENTORY
[40]  INVENTORY←0
[41]  J←J+1
[42]  →(J≤ρTM)/LP2
[43]  'TOTAL INVENTORY FOR PAYGRADE GROUP = ',2 0⍕PG[I]
[44]  '(';'OP5=';OP5;')'
[45]  (5,1)PRIN B
[46]  B←0
[47]  I←I+1
[48]  →(I≤ρPG)/LP1
[49] END:→0
    ∇
```

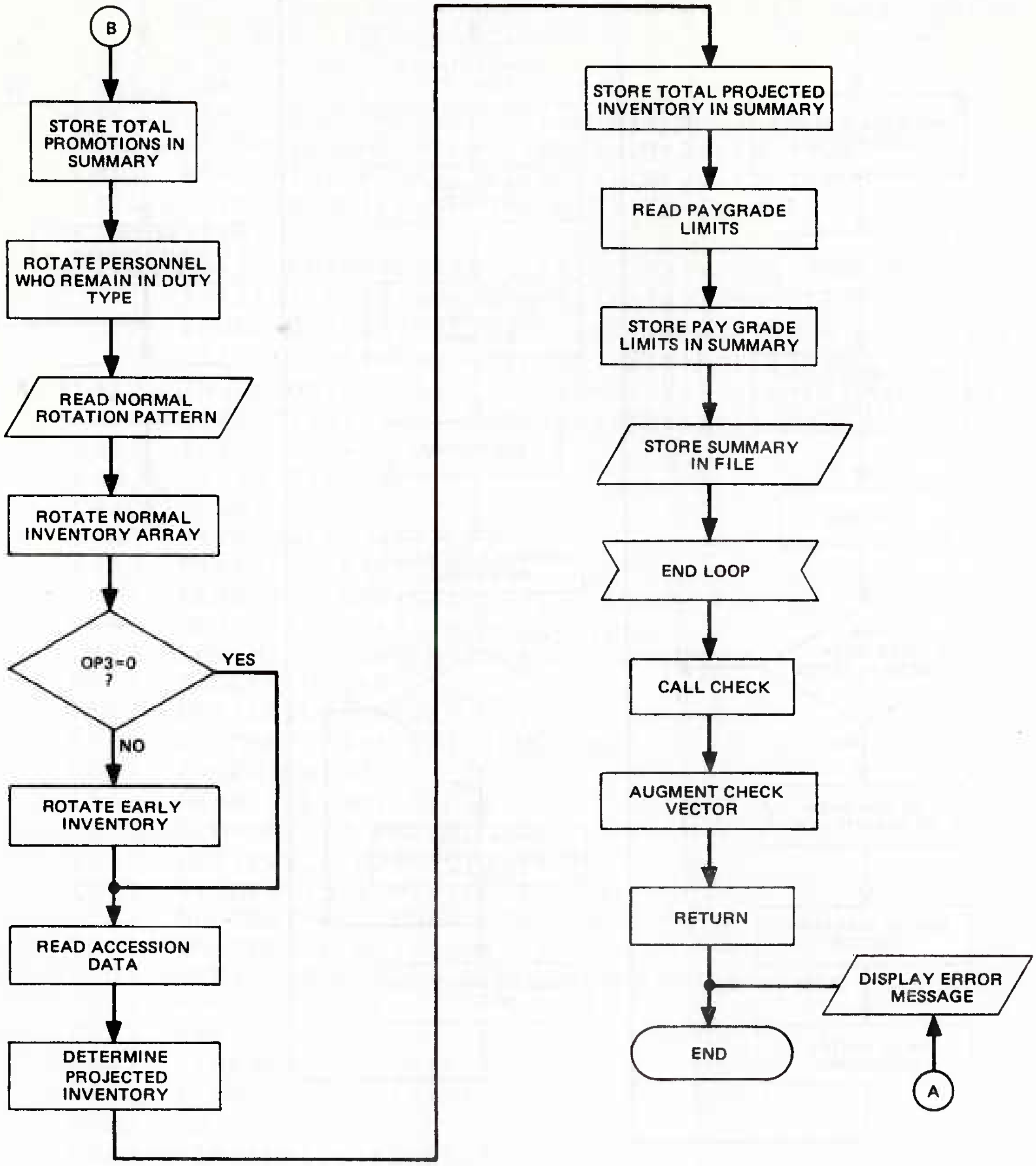
```
    ∇ PRINTT;B;I;J;SUMMARY;TM
      HEADER 5
      →(BR=1)/END
      J←1
     LP1:B←(7,(⍴OP5)÷2)⍴0
      I←1
     LP2:OP6 GROUP OP1,12,I,TM[J]
      B[;I]←SUMMARY
      I←I+1
      →(I≤(⍴OP5)÷2)/LP2
      2 1⍴' '
      '(';'OP5=';OP5;')'
      (6,0)PRIN B
      J←J+1
      →(J≤⍴TM)/LP1
     END:→0
    ∇
```

```
    ∇ PRINTT;A;B;I;J;K;ADJPROBPROM;DU;PG;TM
      HEADER 3
      →(BR=1)/END
      HEADER 5
      →(BR=1)/END
      J←1
      K←COUNT←0
     DUTY:HEADER 2
      →((BR=2)∨BR=1)/END
     LP1:B←(L,⍴PG)⍴0
      I←1
     LP2:READFILE OP1,10,PG[I],TM[J]
      B[;I]←ADJPROBPROM[DU;]
      I←I+1
      →(I≤⍴PG)/LP2
      'ADJUSTED PROMOTION PROBABILITIES FOR DUTY-TYPE:'
      ,A[DU;]
      'IN PERIOD =',2 0⍕TM[J]
      (2,0)PRIN B
      COUNT←COUNT+1
      K←K+DU×COUNT=1
      'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
      PROCEEDING'
      ⍞←'TO THE NEXT TIME PERIOD? '
      →(3≠⍴B←25↓⍞)/CONT
      →(3=+/B='YES')/DUTY
     CONT:DU←K
      J←J+1
      →(J≤⍴TM)/LP1
     END:→0
    ∇
```

```
    ∇ PRINTT;A;INVENTORY;B;C;COUNT;DU;H;I;J;K;PG;TM
[1]    HEADER 4
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    HEADER 6
[6]    →(BR=1)/END
[7]    →(H=1 0)/Q1,Q2
[8]   Q1:HEADER 2
[9]    →((BR=2)∨BR=1)/END
[10]  Q2:I←1
[11]  LP1:B←(3,(⍴TM),3)⍴0
[12]   J←1
[13]  LP2:OP6 GROUP OP1,14,PG[I],TM[J]
[14]   →(H=0)/Q3
[15]   K←COUNT←0
[16]   'SURVIVING INVENTORY FOR PAYGRADE GROUP = ',2 0⍕
       PG[I]
[17]   'IN PERIOD = ',2 0⍕TM[J]
[18]   '(';'OP5=';OP5;')'
[19]   '(';'OP6=';OP6;')'
[20]  DUTY:(3,0)PRIN INVENTORY[DU;;]
[21]   COUNT←COUNT+1
[22]   K←K+DU×COUNT=1
[23]   'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
       PROCEEDING'
[24]   ⍞←'TO THE NEXT PAYGRADE/TIME PERIOD? '
[25]   →(3≠⍴B←34↓⍞)/CONT
[26]   →(3≠+/B='YES')/CONT
[27]   HEADER 2
[28]   →((BR=2)∨BR=1)/END
[29]   →DUTY
[30]  CONT:INVENTORY←0
[31]   DU←K
[32]   J←J+1
[33]   →(J≤⍴TM)/LP2
[34]   I←I+1
[35]   →(I≤⍴PG)/LP1
[36]   →0
[37]  Q3:B[;J;1]←+/+/INVENTORY[;;1,2,3,4]
[38]   B[;J;2]←(+/+/INVENTORY)-+/+/INVENTORY[;;1,2,3,4]
[39]   B[;J;3]←+/+/INVENTORY
[40]   INVENTORY←0
[41]   J←J+1
[42]   →(J≤⍴TM)/LP2
[43]   'TOTAL SURVIVING INVENTORY FOR PAYGRADE GROUP = '
       ,2 0⍕PG[I]
[44]   '(';'OP5=';OP5;')'
[45]   (5,1)PRIN B
[46]   B←0
[47]   I←I+1
[48]   →(I≤⍴PG)/LP1
[49]  END:→0
    ∇
```

```
     ∇ PRINTT;A;INVENTORY;B;C;COUNT;DU;H;I;J;K;PG;TM
[1]    HEADER 4
[2]    →(BR=1)/END
[3]    HEADER 5
[4]    →(BR=1)/END
[5]    HEADER 6
[6]    →(BR=1)/END
[7]    →(H=1 0)/Q1,Q2
[8]   Q1:HEADER 2
[9]    →((BR=2)∨BR=1)/END
[10]  Q2:I←1
[11]  LP1:B←(3,(⍴TM),3)⍴0
[12]   J←1
[13]  LP2:OP6 GROUP OP1,15,PG[I],TM[J]
[14]   →(H=0)/Q3
[15]   K←COUNT←0
[16]   'PREPARED INVENTORY FOR PAYGRADE GROUP = ',2 0⍕
       PG[I]
[17]   'IN PERIOD = ',2 0⍕TM[J]
[18]   '(';'OP5=';OP5;')'
[19]   '(';'OP6=';OP6;')'
[20]  DUTY:(3,0)PRIN INVENTORY[DU;;]
[21]   COUNT←COUNT+1
[22]   K←K+DU×COUNT=1
[23]   'DO YOU WANT TO PRINT ANOTHER DUTY TYPE BEFORE
       PROCEEDING'
[24]   ⍞←'TO THE NEXT PAYGRADE/TIME PERIOD? '
[25]   →(3≠⍴B←34↓⍞)/CONT
[26]   →(3≠+/B='YES')/CONT
[27]   HEADER 2
[28]   →((BR=2)∨BR=1)/END
[29]   →DUTY
[30]  CONT:INVENTORY←0
[31]   DU←K
[32]   J←J+1
[33]   →(J≤⍴TM)/LP2
[34]   I←I+1
[35]   →(I≤⍴PG)/LP1
[36]   →0
[37]  Q3:B[;J;1]←+/+/INVENTORY[;;1,2,3,4]
[38]   B[;J;2]←(+/+/INVENTORY)-+/+/INVENTORY[;;1,2,3,4]
[39]   B[;J;3]←+/+/INVENTORY
[40]   INVENTORY←0
[41]   J←J+1
[42]   →(J≤⍴TM)/LP2
[43]   'TOTAL PREPARED INVENTORY FOR PAYGRADE GROUP = ',
       2 0⍕PG[I]
[44]   '(';'OP5=';OP5;')'
[45]   (5,1)PRIN B
[46]   B←0
[47]   I←I+1
[48]   →(I≤⍴PG)/LP1
[49]  END:→0
     ∇
```

```
     ∇PROJECT[⎕]∇
    ∇ PROJECT T
[1]    ⎕FX⌹[39]'MOD'
[2]    PROJECTT T
[3]    ⎕EX'PROJECTT'
    ∇


   ∇ PROJECTT T;ACCESSIONS;A1;A2;A3;A4;A5;A6;B1;B2;B3;
     B4;B5;B6;CH;CONTINUATION;HOLD;HOLD41;HOLD42;
     HOLD51;HOLD52;I;INVENTORY;J;K;N1;N2;N3;N4;NROT;
     PGLIM;PROMSUM;SUMMARY;TT
[1]    TT←(×/OP4)+T×1-OP4[1]
[2]    →(OP4[1]=1)/START
[3]    0 CHECK(3↑OP1),TT
[4]    →(CH=0)/0
[5]   START:'PROJECTION BEGINNING'
[6]    K←K
[7]   LP1:SUMMARY←K,6⍴0
[8]    READFILE OP1,11,K,TT-1-OP4[1]
[9]    SUMMARY[2]←+/+/+/INVENTORY
[10]   INVENTORY←0
[11]   ATTRITION OP1,K,TT-1
[12]   SUMMARY[3]←+/+/+/INVENTORY
[13]   INVENTORY←0
[14]   PREPINV OP1,K,TT-1
[15]   SUMMARY[4]←PROMSUM
[16]   INVENTORY←4⌽¯1⌽[2]INVENTORY
[17]   READFILE OP1,7,K,TT-1
[18]   J←0
[19]  LP2:A1←NROT[1;]÷((1-J)+J×+/NROT[1;])+1E¯10
[20]   A2←NROT[2;]÷((1-J)+J×+/NROT[2;])+1E¯10
[21]   A3←NROT[3;]÷((1-J)+J×+/NROT[3;])+1E¯10
[22]   A4←NROT[4;]÷((1-J)+J×+/NROT[4;])+1E¯10
[23]   A5←NROT[5;]÷((1-J)+J×+/NROT[5;])+1E¯10
[24]   A6←NROT[6;]÷((1-J)+J×+/NROT[6;])+1E¯10
[25]   →(OP3=0)/Q1
[26]   B1←(((3,L,4)⍴(,HOLD41)\HOLD42)[1;;]×J)+INVENTORY[
       1;;(M-3),(M-2),(M-1),M]×1-J
[27]   B2←(((3,L,4)⍴(,HOLD51)\HOLD52)[1;;]×J)+INVENTORY[
       1;;(M-3),(M-2),(M-1),M]×1-J
[28]   B3←(((3,L,4)⍴(,HOLD41)\HOLD42)[2;;]×J)+INVENTORY[
       2;;(M-3),(M-2),(M-1),M]×1-J
[29]   B4←(((3,L,4)⍴(,HOLD51)\HOLD52)[2;;]×J)+INVENTORY[
       2;;(M-3),(M-2),(M-1),M]×1-J
[30]   B5←(((3,L,4)⍴(,HOLD41)\HOLD42)[3;;]×J)+INVENTORY[
```


B
STORE TOTAL PROMOTIONS IN SUMMARY
ROTATE PERSONNEL WHO REMAIN IN DUTY TYPE
READ NORMAL ROTATION PATTERN
ROTATE NORMAL INVENTORY ARRAY
OP3=0 ?
YES
NO
ROTATE EARLY INVENTORY
READ ACCESSION DATA
DETERMINE PROJECTED INVENTORY
STORE TOTAL PROJECTED INVENTORY IN SUMMARY
READ PAYGRADE LIMITS
STORE PAY GRADE LIMITS IN SUMMARY
STORE SUMMARY IN FILE
END LOOP
CALL CHECK
AUGMENT CHECK VECTOR
RETURN
DISPLAY ERROR MESSAGE
END
A

```
     ∇ STATUS
[1]    □FX■[36]'MOD'
[2]    STATUSS
[3]    □EX'STATUSS'
     ∇
```

```
    ∇ STATUSS
[1]   'K = ';K;'                                         ';'OP2 = ';
      OP2
[2]   'L = ';L;'                                        ';'OP3 = ';
      OP3
[3]   'M = ';M;'                                         ';'I = ';I
[4]   'OP1 = ';OP1
[5]   ' '
[6]   'OP4 = ';OP4
[7]   'OP5 = ';OP5
[8]   'OP6 = ';OP6
[9]   ' '
[10]  '----------------------'
[11]  ' '
[12]  ' TM = ';¯1+⍳I+1
[13]  ' '
[14]  →((⍴■[1+I]'FILE3')=0)/Q1
[15]  'COA = ';■[1+I]'FILE3'
[16] Q1:→((⍴■[2+I]'FILE3')=0)/Q2
[17]  'COP = ';■[2+I]'FILE3'
[18] Q2:' '
[19]  →((⍴■[3+2×I]'FILE3')=0)/Q3
[20]  'C1A = ';■[3+2×I]'FILE3'
[21] Q3:→((⍴■[4+2×I]'FILE3')=0)/0
[22]  'C1P = ';■[4+2×I]'FILE3'
    ∇
```

```
     ∇ TRANSFER
[1]    ⎕FX⍞[52]'MOD'
[2]    TRANSFERR
[3]    ⎕EX'TRANSFERR'
     ∇



     ∇ TRANSFERR;I;J;DT;PG;TM;BILTS;PGLIM;PROBPROM;ELIG;
       CONTINUATION;EROT;NROT;LROT;ACCESSIONS;
       PROMOTIONS;INVENTORY;SUMMARY;ADJPROBPROM;BR;B;X
[1]    'TO WHICH COMPARTMENT (0 OR 1) IS DATA TO BE
       TRANSFERED?'
[2]    X←(~I),I←⎕
[3]    ⍞←'DO YOU WANT TO TRANSFER AN ENTIRE DATA FILE? '
[4]    →(3≠⍴B←45↓⍞)/LOOP
[5]    →(3=+/B='YES')/ALL
[6]   LOOP:HEADER 1
[7]    →((BR=2)∨BR=1)/END
[8]    HEADER 3
[9]    →((BR=2)∨BR=1)/END
[10]  RET:HEADER 5
[11]   →((BR=2)∨BR=1)/END
[12]   →(DT=1 2 11)/BEGIN
[13]   →(0≠+/TM>4)/ERR
[14]  BEGIN:J←1
[15]  LOOP1:I←1
[16]  LOOP2:READFILE X[1],DT,PG[I],TM[J]
[17]   WRITEFILE X[2],DT,PG[I],TM[J]
[18]   →((⍴PG)≥I←I+1)/LOOP2
[19]   →(DT=1)/CONT1
[20]   (X[2],1)FILEALT TM[J]
[21]  CONT1:→(DT∊1,6,7,8)/CONT2
[22]   (X[2],0)FILEALT TM[J]
[23]  CONT2:→((⍴TM)≥J←J+1)/LOOP1
[24]   ⍞←'DO YOU WANT TO TRANSFER ANOTHER DATA TYPE? '
[25]   →(3≠⍴B←43↓⍞)/END
[26]   →(3=+/B='YES')/LOOP
[27]  END:→0
[28]  ALL:⍞←'DATA FILE TO BE TRANSFERED:'
```

```
[29]  →(5≠⍴B←27↓⍞)/ALL
[30]  I←1
[31]  →(B[5]='1234')/LOOP3,LOOP4,LOOP5,LOOP6
[32]  →ALL
[33] LOOP3:(⎕[I+X[1]×8+4×I̲]'FILE1')⎕[I+X[2]×8+4×I̲]'
      FILE1'
[34]  →((8+4×I̲)≥I←I+1)/LOOP3
[35]  →0
[36] LOOP4:(⎕[I+X[1]×2×K̲×I̲+1]'FILE2')⎕[I+X[2]×2×K̲×I̲+1]'
      FILE2'
[37]  →((2×K̲×I̲+1)≥I←I+1)/LOOP4
[38]  →0
[39] LOOP5:(⎕[I+X[1]×I̲+2]'FILE3')⎕[I+X[2]×I̲+2]'FILE3'
[40]  →((I̲+2)≥I←I+1)/LOOP5
[41]  →0
[42] LOOP6:(⎕[I+X[1]×1+2×K̲×I̲+1]'FILE4')⎕[I+X[2]×1+2×K̲×
      I̲+1]'FILE4'
[43]  →((1+2×K̲×I̲+1)≥I←I+1)/LOOP6
[44]  →0
[45] ERR:'FOR THIS DATA TYPE EACH ENTRY MUST LIE IN
      THE'
[46]  'INTERVAL 0 ≤ X ≤ ',2 0⍕I̲-1
[47]  →RET
    ∇
```

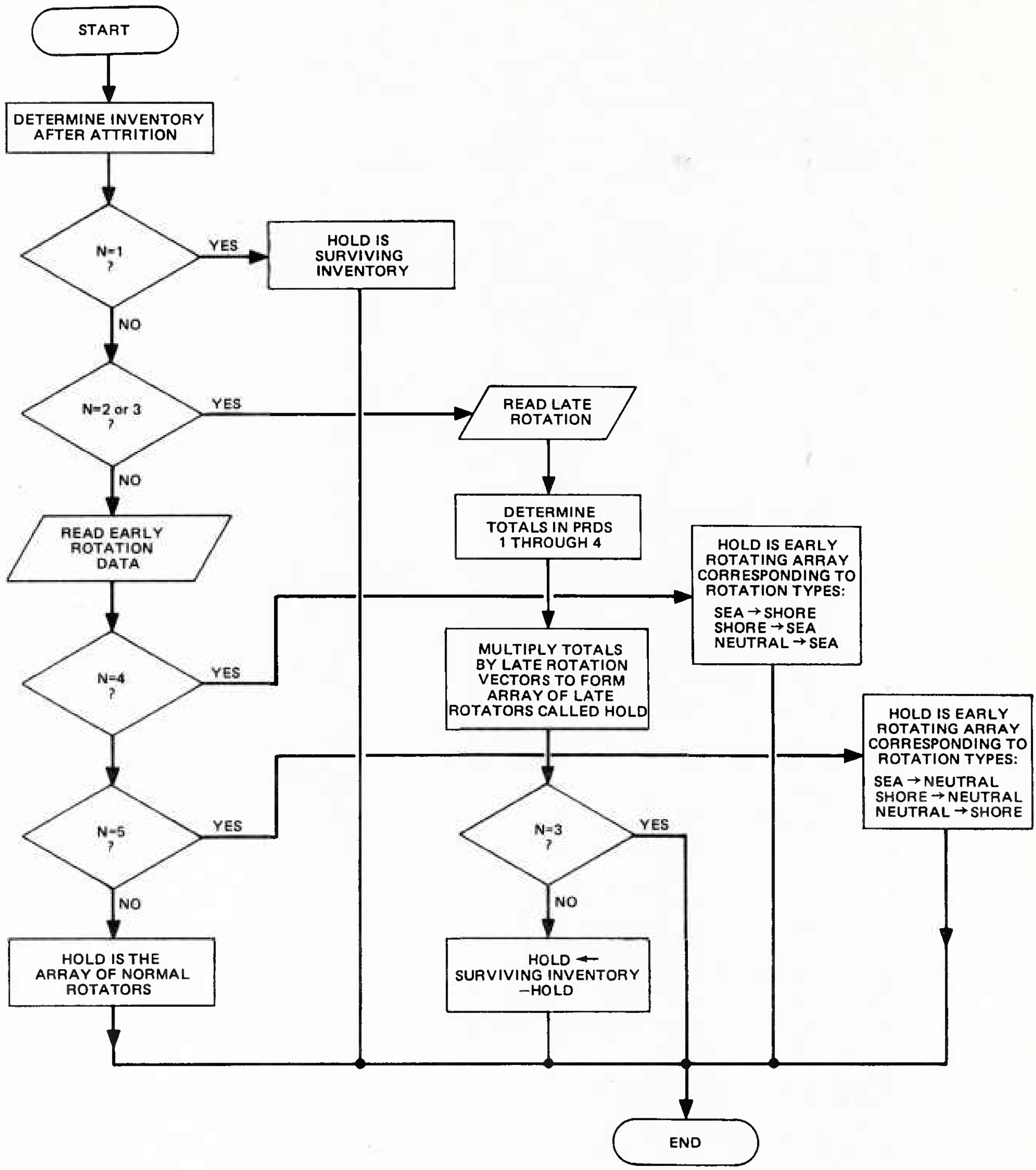
```
    ∇ READFILE X;B;C;I;J;K;L
[1]   I←(8+4×I̲)×X[1]
[2]   L←X[1]+J←2×(I̲+1)×K̲×X[1]
[3]   →(X[2]=1,2,3,4,5,6,7,8,9,10,11,12)/L1,L2,L3,L4,
      L5,L6,L7,L8,L9,L10,L11,L12
[4]  L1:BILTS←(⎕[1+I]'FILE1')[X[3];X[4]+1;]
[5]   →0
[6]  L2:PGLIM←(⎕[2+I]'FILE1')[X[4]+1;X[3]]
[7]   →0
[8]  L3:PROBPROM←(⎕[3+I]'FILE1')[;;X[3]]
[9]   →0
[10] L4:ELIG←(⎕[4+I]'FILE1')[;;X[3]]
[11]  →0
[12] L5:CONTINUATION←(L̲,3)⍴0
[13]  K←1
[14] LP:CONTINUATION[;K]←(⎕[4+K+I]'FILE1')[X[4]+1;;X[3]
      ]
[15]  K←K+1
[16]  →(K≤3)/LP
[17]  →0
[18] L7:B←⎕[I+9+2×X[4]]'FILE1'
[19]  C←⎕[I+10+2×X[4]]'FILE1'
[20]  NROT←((6,M̲,K̲)⍴(,B)\C)[;;X[3]]
[21]  →0
[22] L9:B←⎕[((J−1)+2×X[3])+2×X[4]×K̲]'FILE2'
[23]  C←⎕[(J+2×X[3])+2×X[4]×K̲]'FILE2'
[24]  ACCESSIONS←(3,L̲,M̲)⍴(,B)\C
[25]  →0
[26] L10:ADJPROBPROM←(⎕[1+X[4]+(I̲+2)×X[1]]'FILE3')[;;X[
      3]]
[27]  →0
[28] L11:B←⎕[(L+2×X[3])+2×X[4]×K̲]'FILE4'
[29]  C←⎕[(L+1+2×X[3])+2×X[4]×K̲]'FILE4'
[30]  INVENTORY←(3,L̲,M̲)⍴(,B)\C
[31]  →0
[32] L12:SUMMARY←(⎕[L+1]'FILE4')[X[4]+1;;X[3]]
[33]  →0
[34] L8:B←⎕[I+9+2×I̲+X[4]]'FILE1'
[35]  C←⎕[I+10+2×I̲+X[4]]'FILE1'
[36]  LROT←((3,M̲,K̲)⍴(,B)\C)[;;X[3]]
[37]  →0
[38] L6:EROT←(⎕[8+I]'FILE1')[X[4]+1;;X[3]]
    ∇
```

```
    ∇ WRITEFILE X;B;C;I;J;K;L
[1]   I←(8+4×I̲)×X[1]
[2]   L←X[1]+J←2×(I̲+1)×K̲×X[1]
[3]   →(X[2]=1,2,3,4,5,6,7,8,9,10,11,12)/L1,L2,L3,L4,
      L5,L6,L7,L8,L9,L10,L11,L12
[4]  L1:B←⎕[1+I]'FILE1'
[5]   B[X[3];X[4]+1;]←BILTS
[6]   B⎕[1+I]'FILE1'
[7]   →0
[8]  L2:B←⎕[2+I]'FILE1'
[9]   B[X[4]+1;X[3]]←PGLIM
[10]  B⎕[2+I]'FILE1'
[11]  →0
[12] L3:B←⎕[3+I]'FILE1'
[13]  B[;;X[3]]←PROBPROM
[14]  B⎕[3+I]'FILE1'
[15]  →0
[16] L4:B←⎕[4+I]'FILE1'
[17]  B[;;X[3]]←ELIG
[18]  B⎕[4+I]'FILE1'
[19]  →0
[20] L5:K←1
[21] LOOP:B←⎕[4+K+I]'FILE1'
[22]  B[X[4]+1;;X[3]]←CONTINUATION[;K]
[23]  B⎕[4+K+I]'FILE1'
[24]  K←K+1
[25]  →(K≤3)/LOOP
[26]  →0
[27] L7:C←⎕[I+9+2×X[4]]'FILE1'
[28]  B←(6,M̲,K̲)⍴(,C)\⎕[I+10+2×X[4]]'FILE1'
[29]  B[;;X[3]]←NROT
[30]  (0≠B)⎕[I+9+2×X[4]]'FILE1'
[31]  ((,0≠B)/,B)⎕[I+10+2×X[4]]'FILE1'
[32]  →0
[33] L9:(0≠ACCESSIONS)⎕[((J-1)+2×X[3])+2×X[4]×K̲]'FILE2'
[34]  ((,0≠ACCESSIONS)/,ACCESSIONS)⎕[(J+2×X[3])+2×X[4]×
      K̲]'FILE2'
[35]  →0
[36] L10:B←⎕[1+X[4]+(I̲+2)×OP1]'FILE3'
[37]  B[;;X[3]]←ADJPROBPROM
[38]  B⎕[1+X[4]+(I̲+2)×OP1]'FILE3'
[39]  →0
[40] L11:(0≠INVENTORY)⎕[(L+2×X[3])+2×X[4]×K̲]'FILE4'
[41]  ((,0≠INVENTORY)/,INVENTORY)⎕[(L+1+2×X[3])+2×X[4]×
      K̲]'FILE4'
```

```
[42]   →0
[43]  L12:B←⎕[L+1]'FILE4'
[44]   B[X[4]+1;;X[3]]←SUMMARY
[45]   B⎕[L+1]'FILE4'
[46]   →0
[47]  L8:C←⎕[I+9+2×I̲+X[4]]'FILE1'
[48]   B←(3,M̲,K̲)⍴(,C)\⎕[I+10+2×I̲+X[4]]'FILE1'
[49]   B[;;X[3]]←LROT
[50]   (0≠B)⎕[I+9+2×I̲+X[4]]'FILE1'
[51]   ((,0≠B)/,B)⎕[I+10+2×I̲+X[4]]'FILE1'
[52]   →0
[53]  L6:B←⎕[8+I]'FILE1'
[54]   B[X[4]+1;;X[3]]←EROT
[55]   B⎕[8+I]'FILE1'
     ∇
```

```
     ∇ N ALTER X
[1]    ⎕FX8[37]'MOD'
[2]    N ALTERR X
[3]    ⎕EX'ALTERR'
     ∇



     ∇ N ALTERR X;A;A1;A2;B;B1;B2;EROT;H;I;INVENTORY;J;
       LROT
[1]    ATTRITION X
[2]    →(N=1,2,3,4,5,6)/L1,L2,L3,L4,L5,L6
[3]   L1:HOLD←INVENTORY
[4]    →0
[5]   L2:HOLD←(3,L,M)⍴0
[6]    READFILE X[1],8,X[2],X[3]
[7]    A←+/INVENTORY[;;1,2,3,4]
[8]    INVENTORY←0
[9]    B←(((1,L,M)⍴LROT[1;]),[1](1,L,M)⍴LROT[2;]),[1](1,
       L,M)⍴LROT[3;]
[10]   HOLD←B×(3,L,M)⍴((⍉(M,L)⍴A[1;]),[1]⍉(M,L)⍴A[2;]),[
       1]⍉(M,L)⍴A[3;]
[11]   →0
[12]  L3:READFILE X[1],8,X[2],X[3]
[13]   A←1-+/LROT
[14]   INVENTORY[;;1,2,3,4]←INVENTORY[;;1,2,3,4]×(((1,L,
       4)⍴A[1]),[1](1,L,4)⍴A[2]),[1](1,L,4)⍴A[3]
[15]   HOLD←INVENTORY
[16]   INVENTORY←0
[17]   →0
[18]  L4:READFILE X[1],6,X[2],X[3]
[19]   A←1 0 1 0 1 0/EROT
[20]   B←(((1,L,M-4)⍴A[1]),[1](1,L,M-4)⍴A[2]),[1](1,L,M-
       4)⍴A[3]
[21]   H←+/(B×INVENTORY[;;4+⍳M-4])÷4
[22]   B←INVENTORY←0
[23]   HOLD←(3,L,4)⍴((⍉(4,L)⍴H[1;]),[1]⍉(4,L)⍴H[2;]),[1]
       ⍉(4,L)⍴H[3;]
[24]   →0
[25]  L5:READFILE X[1],6,X[2],X[3]
[26]   A←0 1 0 1 0 1/EROT
[27]   B←(((1,L,M-4)⍴A[1]),[1](1,L,M-4)⍴A[2]),[1](1,L,M-
       4)⍴A[3]
```

```
[28]  H←+/(B×INVENTORY[;;4+⍳M-4])÷4
[29]  B←INVENTORY←0
[30]  HOLD←(3,L,4)⍴((⍉(4,L)⍴H[1;]),[1]⍉(4,L)⍴H[2;]),[1]
      ⍉(4,L)⍴H[3;]
[31]  →0
[32] L6:READFILE X[1],6,X[2],X[3]
[33]  A1←1 0 1 0 1 0/EROT
[34]  A2←0 1 0 1 0 1/EROT
[35]  B←(((1,L,M-4)⍴A1[1]+A2[1]),[1](1,L,M-4)⍴A1[2]+A2[
      2]),[1](1,L,M-4)⍴A1[3]+A2[3]
[36]  J←1
[37] LOOP:INVENTORY[J;;4+⍳M-4]←INVENTORY[J;;4+⍳M-4]×1-
      B[J;;]
[38]  J←J+1
[39]  →(J≤3)/LOOP
[40]  B←0
[41]  HOLD←INVENTORY
    ∇
```


START
DETERMINE INVENTORY AFTER ATTRITION
N=1 ?
YES
NO
HOLD IS SURVIVING INVENTORY
N=2 or 3 ?
YES
NO
READ LATE ROTATION
DETERMINE TOTALS IN PRDS 1 THROUGH 4
READ EARLY ROTATION DATA
HOLD IS EARLY ROTATING ARRAY CORRESPONDING TO ROTATION TYPES:
SEA → SHORE
SHORE → SEA
NEUTRAL → SEA
N=4 ?
YES
MULTIPLY TOTALS BY LATE ROTATION VECTORS TO FORM ARRAY OF LATE ROTATORS CALLED HOLD
HOLD IS EARLY ROTATING ARRAY CORRESPONDING TO ROTATION TYPES:
SEA → NEUTRAL
SHORE → NEUTRAL
NEUTRAL → SHORE
N=5 ?
YES
NO
N=3 ?
YES
NO
HOLD IS THE ARRAY OF NORMAL ROTATORS
HOLD ← SURVIVING INVENTORY −HOLD
END

```
     ∇ ATTRITION X;I;CONTINUATION
[1]    READFILE X[1],5,X[2],X[3]
[2]    READFILE X[1],11,X[2],X[3]+OP4[1]
[3]    I←1
[4]   LP:INVENTORY[I;;]←INVENTORY[I;;]×⍉(M,L)⍴
       CONTINUATION[;I]
[5]    I←I+1
[6]    →(I≤3)/LP
     ∇


     ∇ X CHECK Z;COA;C1A;COP;C1P
[1]    ⎕FX■[30+Z[1]]'MOD'
[2]    X CHECKK Z[2]
[3]    ⎕EX'CHECKK'
     ∇


     ∇ X CHECKK T;I
[1]    →(X=1)/SEC
[2]    →((T<0)∨T≥I̲)/ERR1
[3]    COA←■[1+I̲]'FILE3'
[4]    COP←■[2+I̲]'FILE3'
[5]    →((⍴COP)<T+1)/ERR2
[6]    →((⍴COA)=0)/DEF1
[7]    I←1
[8]   LOOP:→((T≥I)∧COA[I]≠0)/ERR3
[9]    I←I+1
[10]   →(I<(T+1)⌊⍴COA)/LOOP
[11]  DEF1:CH←1
[12]   →0
[13]  ERR1:'T MUST BE IN THE INTERVAL 0≤T<';I̲
[14]   →DEF2
[15]  ERR2:'INVENTORY HAS NOT BEEN COMPUTED FOR PERIOD '
       ;T
[16]   →DEF2
[17]  ERR3:'DATA AFFECTING THIS COMPUTATION HAS BEEN
       ALTERED;'
[18]   'A VALID COMPUTATION REQUIRES 0≤T≤';I-1
[19]  DEF2:CH←0
[20]   →0
[21]  SEC:((T+1)⍴0)■[1+I̲]'FILE3'
     ∇
```

```
    ∇ X CHECKK T;I
[1]   →(X=1)/SEC
[2]   →((T<0)∨T≥I)/ERR1
[3]   C1A←⎕[3+2×I]'FILE3'
[4]   C1P←⎕[4+2×I]'FILE3'
[5]   →((⍴C1P)<T+1)/ERR2
[6]   →((⍴C1A)=0)/DEF1
[7]   I←1
[8]  LOOP:→((T≥I)∧C1A[I]≠0)/ERR3
[9]   I←I+1
[10]  →(I<(T+1)⌊⍴C1A)/LOOP
[11] DEF1:CH←1
[12]  →0
[13] ERR1:'T MUST BE IN THE INTERVAL 0≤T<';I
[14]  →DEF2
[15] ERR2:'INVENTORY HAS NOT BEEN COMPUTED FOR PERIOD '
      ;T
[16]  →DEF2
[17] ERR3:'DATA AFFECTING THIS COMPUTATION HAS BEEN
      ALTERED;'
[18]  'A VALID COMPUTATION REQUIRES 0≤T≤';I−1
[19] DEF2:CH←0
[20]  →0
[21] SEC:((T+1)⍴0)⎕[3+2×I]'FILE3'
    ∇
```

```
    ∇ X CHECKK T;I
[1]   →(X=1)/SEC
[2]   →((T<1)∨T>I)/ERR1
[3]   COA←⎕[1+I]'FILE3'
[4]   COP←⎕[2+I]'FILE3'
[5]   →((⍴COA)<T)/ERR2
[6]   →((⍴COP)=0)/DEF1
[7]   I←1
[8]  LOOP:→((T>I)∧COP[I]≠0)/ERR3
[9]   I←I+1
[10]  →(I<T⌊⍴COP)/LOOP
[11]  →(COA[T]=1)/ERR4
[12] DEF1:CH←1
[13]  →0
[14] ERR1:'T MUST BE IN THE INTERVAL 0<T≤';I
[15]  →DEF2
[16] ERR2:'ADJUSTED PROBABILITIES HAVE NOT BEEN
      COMPUTED FOR PERIOD ';T−1
[17]  →DEF2
[18] ERR3:'DATA AFFECTING THIS COMPUTATION HAS BEEN
      ALTERED;'
```

```
[19]  'A VALID COMPUTATION REQUIRES 0≤T≤';I
[20]  →DEF2
[21] ERR4:'ADJUSTED PROBABILITIES ARE NOT VALID FOR
      PERIOD ';T-1
[22] DEF2:CH←0
[23]  →0
[24] SEC:((T+1)⍴0)⍈[2+I]'FILE3'
    ∇



    ∇ X CHECKK T;I
[1]   →(X=1)/SEC
[2]   →((T<1)∨T>I)/ERR1
[3]   C1A←⍈[3+2×I]'FILE3'
[4]   C1P←⍈[4+2×I]'FILE3'
[5]   →((⍴C1A)<T)/ERR2
[6]   →((⍴C1P)=0)/DEF1
[7]   I←1
[8]  LOOP:→((T>I)∧C1P[I]≠0)/ERR3
[9]   I←I+1
[10]  →(I<T⌊⍴C1P)/LOOP
[11]  →(C1A[T]=1)/ERR4
[12] DEF1:CH←1
[13]  →0
[14] ERR1:'T MUST BE IN THE INTERVAL 0<T≤';I
[15]  →DEF2
[16] ERR2:'ADJUSTED PROBABILITIES HAVE NOT BEEN
      COMPUTED FOR PERIOD ';T-1
[17]  →DEF2
[18] ERR3:'DATA AFFECTING THIS COMPUTATION HAS BEEN
      ALTERED;'
[19]  'A VALID COMPUTATION REQUIRES 0≤T≤';I
[20]  →DEF2
[21] ERR4:'ADJUSTED PROBABILITIES NOT VALID FOR PERIOD
      ';T-1
[22] DEF2:CH←0
[23]  →0
[24] SEC:((T+1)⍴0)⍈[4+2×I]'FILE3'
    ∇
```

```
    ∇ FFF;I;E;ELIG;NORMPROM;PROB;PROBPROM;W
[1]    READFILE OP1,3,K,T
[2]    READFILE OP1,4,K,T
[3]    PROB←PROBPROM⌊ELIG
[4]    NORMPROM←E←0
[5]    I←1
[6]   LP:NORMPROM←NORMPROM++/PROB[I;]×+/[2]INVENTORY[I;;
      ]
[7]    E←E++/ELIG[I;]×+/[2]INVENTORY[I;;]
[8]    I←I+1
[9]    →(I≤3)/LP
[10]   →(NORMPROM>AVAILSLOTS)/LL
[11]   →(E=NORMPROM)/LLL
[12]   W←1⌊(AVAILSLOTS−NORMPROM)÷E−NORMPROM
[13]   ADJPROBPROM←((1−W)×PROB)+W×ELIG
[14]   →0
[15]  LL:ADJPROBPROM←(AVAILSLOTS÷NORMPROM)×PROB
[16]   →0
[17]  LLL:ADJPROBPROM←PROB
    ∇



    ∇ X FILEALT T
[1]    ⎕FX■[35]'MOD'
[2]    X FILEALTT T
[3]    ⎕EX'FILEALTT'
    ∇
```

```
     ∇ X FILEALTT T;COA;COP;C1A;C1P
[1]    →(2=+/X=0 0)/L1
[2]    →(2=+/X=0 1)/L2
[3]    →(2=+/X=1 0)/L3
[4]    →(2=+/X=1 1)/L4
[5]   L1:COA←⌹[1+⌶]'FILE3'
[6]    →(T≥⍴COA)/0
[7]    COA[T+1]←1
[8]    COA⌹[1+⌶]'FILE3'
[9]    →0
[10]  L2:COP←⌹[2+⌶]'FILE3'
[11]   →(T≥⍴COP)/0
[12]   COP[T+1]←1
[13]   COP⌹[2+⌶]'FILE3'
[14]   →0
[15]  L3:C1A←⌹[3+2×⌶]'FILE3'
[16]   →(T≥⍴C1A)/0
[17]   C1A[T+1]←1
[18]   C1A⌹[3+2×⌶]'FILE3'
[19]   →0
[20]  L4:C1P←⌹[4+2×⌶]'FILE3'
[21]   →(T≥⍴C1P)/0
[22]   C1P[T+1]←1
[23]   C1P⌹[4+2×⌶]'FILE3'
     ∇
```

```
     ∇ Z GROUP X
[1]    ⎕FX⌹[7]'MOD'
[2]    Z GROUPP X
[3]    ⎕EX'GROUPP'
     ∇
```

```
    ∇ Z GROUPP X;A;ADJPROBPROM;B;C;HOLD;HOLD41;HOLD42;
      HOLD51;HOLD52;I;PROMSUM
[1]   C←0
[2]   I←OP5[(2×X[3])-1]
[3]  LOOP1:→(X[2]=1,2,9,10,11,12,14,15)/L1,L2,L9,L10,
      L11,L12,L14,L15
[4]  L1:READFILE X[1],1,I,X[4]
[5]   C←C+BILTS
[6]   →LL
[7]  L2:READFILE X[1],2,I,X[4]
[8]   C←C+PGLIM
[9]   →LL
[10] L9:READFILE X[1],9,I,X[4]
[11]  C←C+ACCESSIONS
[12]  ACCESSIONS←0
[13]  →LL
[14] L10:→(I=1)/LL10
[15]  1 ALTER X[1],(I-1),X[4]
[16]  READFILE X[1],10,(I-1),X[4]
[17]  C←HOLD×(3,L̲,M̲)ρ((⍉(M̲,L̲)ρADJPROBPROM[1;]),[1]⍉(M̲,
      L̲)ρADJPROBPROM[2;]),[1]⍉(M̲,L̲)ρADJPROBPROM[3;]
[18]  ADJPROBPROM←HOLD←0
[19]  →LLL
[20] LL10:C←(3,L̲,M̲)ρ0
[21]  →LLL
[22] L11:READFILE X[1],11,I,X[4]
[23]  C←C+INVENTORY
[24]  INVENTORY←0
[25]  →LL
[26] L12:READFILE X[1],12,I,X[4]
[27]  SUMMARY[1]←X[3]
[28]  →(I=OP5[(2×X[3])-1])/KK
[29]  SUMMARY[1,4]←0 0
[30] KK:C←C+SUMMARY
[31]  →LL
[32] L14:1 ALTER X[1],I,X[4]
[33]  C←C+HOLD
[34]  HOLD←0
[35]  →LL
[36] L15:PREPINV X[1],I,X[4]
[37]  →(OP3≠1)/AA
[38]  INVENTORY[;;1,2,3,4]←INVENTORY[;;1,2,3,4]+((3,L̲,
      4)ρ(,HOLD41)\HOLD42)+(3,L̲,4)ρ(,HOLD51)\HOLD52
[39] AA:C←C+INVENTORY
[40]  HOLD41←HOLD42←HOLD51←HOLD52←INVENTORY←0
[41] LL:I←I+1
[42]  →(I≤OP5[2×X[3]])/LOOP1
[43] LLL:→(X[2]=1,2,12)/QQ
[44]  B←(3,((ρZ)÷2),M̲)ρ0
```

```
[45]  I←1
[46] LOOP2:B[;I;]←+/[2]C[⍋(Z[(2×I)-1]-1)+⍳1+Z[2×I]-Z[(
      2×I)-1];]
[47]  I←I+1
[48]  →(I≤(⍴Z)÷2)/LOOP2
[49] QQ:→(X[2]=1,2,9,10,11,12,14,15)/Q1,Q2,Q9,Q10,Q11,
      Q12,Q14,Q15
[50] Q1:BILTS←C
[51]  →0
[52] Q2:PGLIM←C
[53]  →0
[54] Q9:ACCESSIONS←B
[55]  →0
[56] Q10:PROMOTIONS←B
[57]  →0
[58] Q11:INVENTORY←B
[59]  →0
[60] Q12:SUMMARY←C
[61]  →0
[62] Q14:INVENTORY←B
[63]  →0
[64] Q15:INVENTORY←B
    ∇


    ∇ HEADER I
[1]    ⎕FX⍉[24+I]'MOD'
[2]   FNC:HEADERR
[3]    →(BR=0)/FNC
[4]    ⎕EX'HEADERR'
    ∇
```

```
    ∇ HEADERR;A;B
[1]   ⍞←'DATA TYPE: '
[2]   A←17 26⍴'BILLETS                   PAYGRADE
      LIMITS           PROMOTION PROBABILITIES
      ELIGIBLE PROBABILITIES    CONTINUATION
         EARLY ROTATION            NORMAL ROTATION
            LATE ROTATION             ACCESSIONS
               ADJUSTED PROBABILITIES    INVENTORY
                  SUMMARY                   PROMOTIONS
                     SURVIVING INVENTORY
      PREPARED INVENTORY         →C         '
         →
[3]   B←11↓⍞
[4]   DT←1
[5]  LOOP:→(26=+/A[DT;]=B,(26-⍴B)⍴' ')/END
[6]   DT←DT+1
[7]   →(DT≤17)/LOOP
[8]  END:BR←((15⍴3),2,1,0)[DT]
    ∇



    ∇ HEADERR;B
[1]   A←5 7⍴'SEA    SHORE  NEUTRAL→C      →       '
[2]   ⍞←'DUTY TYPE: '
[3]   B←11↓⍞
[4]   DU←1
[5]  LOOP:→(7=+/A[DU;]=B,(7-⍴B)⍴' ')/END
[6]   DU←DU+1
[7]   →(DU≤5)/LOOP
[8]  END:BR←((3⍴3),2,1,0)[DU]
    ∇



    ∇ HEADERR;B;R;A
[1]   BR←3
[2]   ⍞←'ROTATION TYPE:'
[3]   A←8 16⍴'SEA TO SHORE    SEA TO NEUTRAL  SHORE TO
      SEA     SHORE TO NEUTRALNEUTRAL TO SEA   NEUTRAL
      TO SHORE→C             →                '
[4]   R←B,(16-⍴B←14↓⍞)⍴' '
[5]   RT←1
[6]  LOOP:→(16=+/R=A[RT;])/END
[7]   →(8≥RT←RT+1)/LOOP
[8]  END:BR←((6⍴3),2,1,0)[RT]
    ∇
```

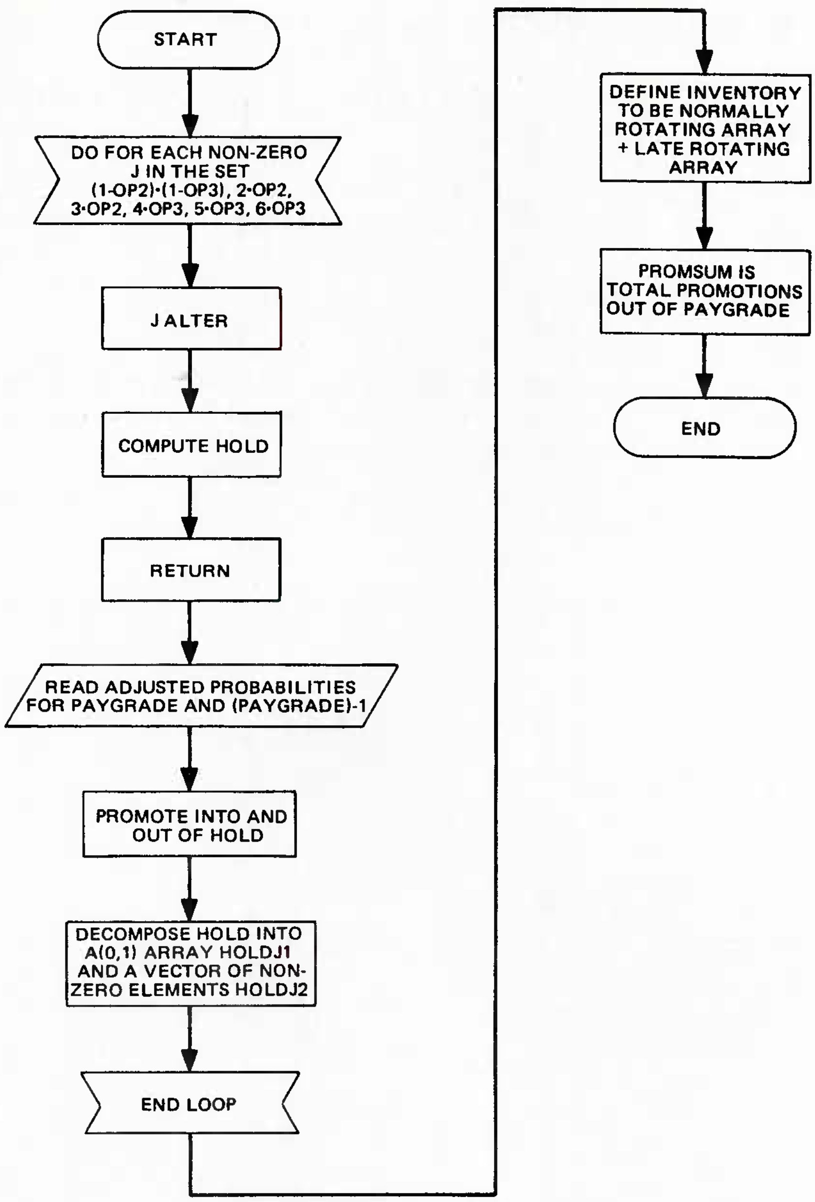
```
[11]  →0
[12] ERROR:'EACH ENTRY MUST LIE IN THE INTERVAL 0 < X ≤
      ',2 0⍕K̲
[13]  BR←0
[14]  →0
[15] END:BR←1
    ∇


    ∇ HEADERR;B;I
[1]   BR←3
[2]   →(0≠2|⍴OP5)/ERROR1
[3]   →((⍴OP5)>2×K̲)/ERROR1
[4]   I←1
[5]  LOOP1:→(OP5[I+1]>K̲)/ERROR1
[6]   →(OP5[I]>OP5[I+1])/ERROR1
[7]   I←I+1
[8]   →(I≤(⍴OP5)-1)/LOOP1
[9]   ⍞←'PAYGRADE GROUPS:'
[10]  B←16↓⍞
[11]  →((B='→')∧(⍴B)=1)/END
[12]  PG←,⍎B
[13]  I←1
[14] LOOP:→(PG[I]>(⍴OP5)÷2)/ERROR2
[15]  →(PG[I]<0)/ERROR2
[16]  I←I+1
[17]  →(I≤⍴PG)/LOOP
[18]  →0
[19] ERROR2:'EACH ENTRY MUST LIE IN THE INTERVAL 0 < X
      ≤',2 0⍕(⍴OP5)÷2
[20]  BR←0
[21]  →0
[22] ERROR1:'PAYGRADE GROUPS NOT DEFINED,CHECK OP5'
[23]  BR←1
[24]  →0
[25] END:BR←1
    ∇
```

```
     ∇ HEADERR;I;B
[1]    BR←3
[2]    ⍞←'TIME PERIODS:'
[3]    B←13↓⍞
[4]    →((B='→')∧(⍴B)=1)/END
[5]    TM←,⍎B
[6]    I←1
[7]   LOOP:→(TM[I]>I)/ERROR
[8]    →(TM[I]<0)/ERROR
[9]    I←I+1
[10]   →(I≤⍴TM)/LOOP
[11]   →0
[12]  ERROR:'EACH ENTRY MUST LIE IN THE INTERVAL 0 ≤ X ≤
       ',2 0⍕I
[13]   BR←0
[14]   →0
[15]  END:BR←1
     ∇
```

```
     ∇ HEADERR;B
[1]    BR←3
[2]    ⍞←'TOTALS OR ARRAY? '
[3]    B←17↓⍞
[4]    →(B='→')/END
[5]    →(6=+/'TOTALS'∊B)/Q1
[6]    →(5=+/'ARRAY'∊B)/Q2
[7]    'INCORRECT ENTRY'
[8]    BR←0
[9]    →0
[10]  Q1:H←0
[11]   →0
[12]  Q2:H←1
[13]   →0
[14]  END:BR←1
     ∇
```

```
    ∇ PREFINV X;ADJPROBPROM;B;C;HOLD;HOLD21;HOLD22;
       HOLD31;HOLD32;HOLD61;HOLD62;J;M
[1]    J←1
[2]   LOOP1:→(J∊((1−OP2)×1−OP3),(2×OP2),(2×OP3),(3×OP2),
       (4×OP3),(5×OP3),6×OP3)/Q1
[3]    →Q2
[4]   Q1:→(X[2]>1)/AA
[5]    C←1 1 1⍴0
[6]    →BB
[7]   AA:J ALTER X[1],(X[2]−1),X[3]
[8]    READFILE X[1],10,(X[2]−1),X[3]
[9]    M←(⍴HOLD)[3]
[10]   C←HOLD×(3,L,M)⍴((⍉(M,L)⍴ADJPROBPROM[1;]),[1]⍉(M,
       L)⍴ADJPROBPROM[2;]),[1]⍉(M,L)⍴ADJPROBPROM[3;]
[11]   HOLD←0
[12]  BB:J ALTER X
[13]   READFILE X[1],10,X[2],X[3]
[14]   M←(⍴HOLD)[3]
[15]   B←HOLD×(3,L,M)⍴((⍉(M,L)⍴ADJPROBPROM[1;]),[1]⍉(M,
       L)⍴ADJPROBPROM[2;]),[1]⍉(M,L)⍴ADJPROBPROM[3;]
[16]   HOLD←C+HOLD−B
[17]   →(J=1,2,3,4,5,6)/L1,L2,L3,L4,L5,L6
[18]  L1:HOLD11←0≠HOLD
[19]   HOLD12←(,HOLD11)/,HOLD
[20]   →Q2
[21]  L2:HOLD21←0≠HOLD
[22]   HOLD22←(,HOLD21)/,HOLD
[23]   →Q2
[24]  L3:HOLD31←0≠HOLD
[25]   HOLD32←(,HOLD31)/,HOLD
[26]   →Q2
[27]  L4:HOLD41←0≠HOLD
[28]   HOLD42←(,HOLD41)/,HOLD
[29]   →Q2
[30]  L5:HOLD51←0≠HOLD
[31]   HOLD52←(,HOLD51)/,HOLD
[32]   →Q2
[33]  L6:HOLD61←0≠HOLD
[34]   HOLD62←(,HOLD61)/,HOLD
[35]  Q2:B←C←HOLD←0
[36]   J←J+1
[37]   →(J≤6)/LOOP1
[38]   →(2=+/(OP2,OP3)=0,0)/Q3
[39]   →(2=+/(OP2,OP3)=1,0)/Q4
```

```
[40]  →(2=+/(OP2,OP3)=1,1)/Q5
[41]  INVENTORY←(3,L̲,M̲)⍴(,HOLD61)\HOLD62
[42]  →Q6
[43] Q3:INVENTORY←(3,L̲,M̲)⍴(,HOLD11)\HOLD12
[44]  →Q6
[45] Q4:INVENTORY←((3,L̲,M̲)⍴(,HOLD31)\HOLD32)+(3,L̲,M̲)⍴(,
      HOLD21)\HOLD22
[46]  →Q6
[47] Q5:INVENTORY←((3,L̲,M̲)⍴(,HOLD21)\HOLD22)+((3,L̲,M̲)⍴(
      ,HOLD31)\HOLD32)[;;1,2,3,4],((3,L̲,M̲)⍴(,HOLD61)\
      HOLD62)[;;4+⍳M̲-4]
[48] Q6:→(X[2]=1)/Q7
[49]  1 ALTER X[1],(X[2]-1),X[3]
[50]  READFILE OP1,10,(X[2]-1),X[3]
[51]  PROMSUM←+/+/+/HOLD×(3,L̲,M̲)⍴((⍉(M̲,L̲)⍴ADJPROBPROM[
      1;]),[1]⍉(M̲,L̲)⍴ADJPROBPROM[2;]),[1]⍉(M̲,L̲)⍴
      ADJPROBPROM[3;]
[52]  →0
[53] Q7:PROMSUM←0
    ∇
```


START
DO FOR EACH NON-ZERO J IN THE SET (1-OP2)·(1-OP3), 2·OP2, 3·OP2, 4·OP3, 5·OP3, 6·OP3
J ALTER
COMPUTE HOLD
RETURN
READ ADJUSTED PROBABILITIES FOR PAYGRADE AND (PAYGRADE)-1
PROMOTE INTO AND OUT OF HOLD
DECOMPOSE HOLD INTO A(0,1) ARRAY HOLDJ1 AND A VECTOR OF NON-ZERO ELEMENTS HOLDJ2
END LOOP
DEFINE INVENTORY TO BE NORMALLY ROTATING ARRAY + LATE ROTATING ARRAY
PROMSUM IS TOTAL PROMOTIONS OUT OF PAYGRADE
END

```
     ∇ I PRINN X
[1]    ⎕FX⍉[I[1]]'MOD'
[2]    I[2]PRIN X
[3]    ⎕EX'PRIN'
     ∇


     ∇ I PRIN X
[1]    2 1⍴' '
[2]    '<PGG= >,A4;I8'⍕(' ';PG)
[3]    2 1⍴' '
[4]    '<TM = >,LI2;A2;I8'⍕(⍉TM;' ';X)
[5]    4 1⍴' '
     ∇


     ∇ I PRIN X
[1]    2 1⍴' '
[2]    '<PG = >,A5;I8'⍕(' ';PG)
[3]    2 1⍴' '
[4]    '<LOS = >,LI2;A2;F8.4'⍕(⍉⍳L;' ';X)
[5]    4 1⍴' '
     ∇


     ∇ I PRIN X
[1]    2 1⍴' '
[2]   LP:→(DU=1,2,3)/A1,A2,A3
[3]   A1:'       SEA'
[4]    →B
[5]   A2:'       SHORE'
[6]    →B
[7]   A3:'       NEUTRAL'
[8]    →B
[9]   B:3 1⍴' '
[10]   '<TL = >,A5;I10'⍕(' ';⍳M)
[11]   2 1⍴' '
[12]   '<LOSG= >,LI2;A2;F10.2'⍕(⍉⍳(⍴OP6)÷2;' ';X)
[13]   ' '
     ∇
```

```
     ∇ I PRIN X
       2 1⍴' '
       →(I=1)/Q1
       'ROTATION:   SE→SH   SE→NT   SH→SE   SH→NT   NT→
       SE   NT→SH'
       2 1⍴' '
       →(I=2)/Q2
       '<TL = >,LI2;A2;F8.4'⍕(⍉\M̲;' ';X)
       4 1⍴' '
       →0
      Q1:'DUTY TYPE:          SEA        SHORE      NEUTRAL'
       2 1⍴' '
       '<TL = >,LI2;A2;F12.4'⍕(⍉\M̲;' ';X)
       4 1⍴' '
       →0
      Q2:'<PG = >,LI2;A2 ;F8.4'⍕(⍉PG;' ';X)
       4 1⍴' '
     ∇


     ∇ I PRIN X
       2 1⍴' '
       'DUTY TYPE:                      SEA
          SHORE                      NEUTRAL'
       2 1⍴' '
       →(I=1)/C
       '<TM = >,LI2;A1;I24'⍕(⍉TM;' ';X)
       4 1⍴' '
       →0
      C:'<TM = >,LI2;A1;I8;I8;I8'⍕(⍉TM;' ';X[1;;];X[2;;]
       ;X[3;;])
       4 1⍴' '
     ∇
```

```
    ∇ I PRIN X;A;N;Z
[1]    ' '
[2]    A←7 32⍴'PAYGRADE GROUP                    INITIAL
       INVENTORY FOR PERIOD    INVENTORY AFTER
       ATTRITION       PROMOTIONS INTO PAYGRADE GROUP
       ACCESSIONS INTO PAYGRADE GROUP  PAYGRADE GROUP
       LIMITS FOR PERIODPROJECTED INVENTORY FOR PERIOD
       '
[3]    Z←+/X[2,3,4,5,6,7;]
[4]    Z[3]←0
[5]    N←(1 0⍕TM[J]),'    ',(1 0⍕TM[J]+1),1 0⍕TM[J]+1
[6]    'A1;A1;I6'⍕(A[1;];'     ';X[1;])
[7]    'A1;A1;A1;A2;I6;A4;I6'⍕(A[2,3,4,5,6,7;];' ';⍉N;'
       ';X[2,3,4,5,6,7;];' ';⍉Z)
    ∇
```

APPENDIX C

PARAMETERS

APPENDIX C

PARAMETERS

Fixed parameters. These parameters define the size of the data structures in the file system. For a detailing community, they remain fixed throughout the analysis.

T

This is the maximum number of years to which the initial inventory will be projected.

M

This is the maximum tour length in quarters.

L

This is the number of length of service categories.

K

This is the number of paygrades.

Variable parameters. These parameters can be modified by the user at any time; they control the operation of specific ROTATIONMOD functions.

Op1(=0 or 1)

All ROTATIONMOD functions will access the (Op1)-compartment of the data files.

Op2(=0 or 1)

Late rotation data is included in projecting the inventory if and only if Op2 = 1.

Op3(=0 or 1)

Early rotation data is included in projecting the inventory if and only if Op3 = 1.

Op4

This 2-component vector is used to project beyond the normal limit of T periods. If Op4[1] = 0, there is no effect. However, when Op4[1] = 1 and Op4[2] = T, then input data located in the period T-1 space will be used to project the inventory stored at period T. The result is stored in the period T space, destroying all previous contents. Op4 must satisfy:

- Op4[1] = 0 or 1
- $0 < Op4[2] \leq \underline{T}$

Op5

This vector aggregates paygrades. The m-th paygrade group defined by Op5 is the aggregate of all paygrades k, where $Op5[2m-1] \leq k \leq Op5[2m]$. Op5 must satisfy:

- Op5 has an even number of components
- All components are between 1 and $\underline{K}$ inclusive
- The number of components is between 2 and $2\underline{K}$ inclusive

Op6

This vector aggregates length of service (LOS) categories. The m-th LOS group defined by Op6 is the aggregate of all LOS categories ℓ, where $Op6[2m-1] \leq \ell \leq Op6[2m]$. Op6 must satisfy:

- Op6 has an even number of components
- All components are between 1 and $\underline{L}$ inclusive
- The number of components is between 2 and $2\underline{L}$ inclusive

Check parameters. These parameters are automatically determined by the operation of ROTATIONMOD functions. Their purpose is to check the consistency of input/output data.

COA

The number of components in this binary vector is the number of periods for which adjusted promotion probabilities have been computed in the 0-compartment. A 1 appears in the i-th component if, subsequent to the computation, data affecting period i-1 has been altered.

COP

The number of components in this binary vector is the number of periods to which the initial inventory has been projected in the 0-compartment. A 1 appears in the i-th component if, subsequent to the projection, data affecting period i has been altered.

C1A

The number of components in this binary vector is the number of periods for which adjusted promotion probabilities have been computed in the 1-compartment. A 1 appears in the i-th component if, subsequent to the computation, data affecting period i-1 has been altered.

C1P

The number of components in this binary vector is the number of periods to which the initial inventory has been projected in the 1-compartment. A 1 appears in the i-th component if, subsequent to the projection, data affecting period i has been altered.